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BERNARDO A. BALLESTEROS

March 15, 2022

VIA EMAIL

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
2407 N. Grand River Ave
Lansing, MI 48906

Re: 2021 Michigan Uniform Energy Code; Administrative Rules Part 10

Ladies and Gentlemen:

I am writing on behalf of the Home Builders Association of Michigan concerning the proposed adoption of the residential provisions of the International Energy Conservation Code, 2021 Edition.

The provisions of the governing statute, the Stille-DeRossett-Hale Construction Code Act, MCL 125.1504(3), for energy conservation, direct that the code effectuate specific standards:

> (f) To provide standards and requirements for cost-effective energy efficiency that will be effective April 1, 1997.
>
> (g) Upon periodic review, to continue to seek ever-improving, cost-effective energy efficiencies.
>
> (h) To develop a voluntary consumer information system relating to energy efficiencies.

The term "cost-effective" is defined in section 2a, MCL 125.1502a:

> (p) "Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:

(i) Considers the perspective of a typical first-time home buyer.

(ii) Considers benefits and costs over a 7-year time period.

(iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.

(iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features.

(v) Ensures that the costs of principal, interest, taxes, insurance, and utilities will not be greater after the inclusion of the proposed cost of the additional energy-saving construction features required by the proposed energy efficiency rules than under the provisions of the existing energy efficiency rules.

In other words, for a new code to be adopted, it must be shown to be "cost-effective" as that term is defined in the statute. As published online, the record provided by the Department to date includes only the Request for Rulemaking ("RFR") and a copy of "2021-48 LR Part 10. Michigan Uniform Energy Code (Strike & Bold)," is nothing more than the adoption by reference of the 2021 IECC.

HBAM and its members believe that whether the statutory standards are met is critical to Michigan housing. That information should be provided before further consideration of the adoption of the 2021 IECC.

Very truly yours,

David E. Pierson

DEP/caj

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2021 Michigan Energy Code Comments

DTE Energy Introduction

DTE Energy serves 2.2 million electric customers in Southeastern Michigan and serves 1.3 million natural gas customers throughout the state of Michigan. DTE is committed to its goal of achieving net-zero carbon emissions by 2050. An important aspect of achieving this goal is focusing on reducing energy waste. DTE's customers will benefit from a range of energy, financial, and environmental benefits that are associated with adopting a more stringent code. Therefore, DTE is in support of the adoption of the 2021 Residential IECC, as proposed by LARA, and recommends one change to further strengthen the code.

DTE's Role to Date in Promoting Energy-Efficient New Home Construction

DTE's Energy Waste Reduction (EWR) portfolio consists of various energy-saving programs, including the DTE New Home Construction Program. This residential, above-code program launched in 2019 and has successfully shown that DTE can influence new homebuilders to adopt energy-efficient enhancements in home construction by providing financial incentives and no-cost training. The New Home Construction Program includes 73 custom and production builders, building on average 1,800 HERS-rated homes annually. The program requires builders to take a whole home approach for building high efficiency homes by requiring all homes to meet a specified HERS Index score. After that prerequisite is met, builders are eligible for financial incentives to help offset energy efficient upgrades including a pay-for-performance incentive for natural gas and electricity saved over building code minimums. Additionally, builders receive financial incentives for high efficiency equipment and measure installation as well as the achievement of ENERGY STAR Certified homes.

DTE's financial incentives and training in its new home construction program decrease the cost of high efficiency new construction practices over time, by paying builders to try new high efficiency techniques, making the ultimate adoption of these practices in code less expensive. DTE paid builders a total of $1.8M incentives in 2021 which increased the adoption of high efficiency building practices that can be incorporated into the new building code. DTE's new home construction program will continue to support above code building through 2023, and beyond, pending program renewal.

With the adoption of a new code, DTE is on track to launch a code compliance training pilot to support builders, trades, and code officials with no-cost training materials, resources, and webinars and/or in-person sessions. The goal of the pilot is to provide streamlined training and guidance on new parts of the energy code, improve compliance rates, and reduce builder costs of compliance with the new code. DTE is interested in collaborating with other state entities and organizations to facilitate training and expand reach across the state.

DTE Supports Michigan Preserving the 2021 IECC (no amendments): Overall Support

The unamended 2021 Residential IECC will improve the energy efficiency in new homes by 12%[1] over Michigan's current residential energy code (the amended 2015 IECC). In particular, continuous insulation, increased efficiency of wall and ceiling insulation, and increased envelope air tightness are crucial to achieving energy savings and reducing utility bill costs, creating healthier and more comfortable buildings, and increasing the resiliency of the building stock being built today.

- In addition to increased thermal efficiency, continuous insulation can reduce thermal bridging, decrease draftiness, and minimize the risk of moisture issues.
- New construction is the most cost-effective time to add insulation to walls and ceilings.
- 3 ACH (50) has been present since the 2012 IECC and is easily achievable.

We recommend not rolling back these requirements.

DTE Supports Michigan's adoption of the 2021 IECC (no amendments): General Support for Customer Economics

DTE understands the monthly energy costs of its customers and works within the EWR collaborative to save its customers energy and money. A higher efficiency code, as proposed by LARA, will cost customers who are purchasing new homes more money up front, but will deliver energy bill savings over the life of the home. When considering these upfront costs, we need to remember that these costs are typically folded into the cost of a 30-year mortgage. In this case, what matters to the monthly budgets of our customers is the increased cost of the mortgage payment compared to the energy bill savings of the customer. If the energy bill savings are larger than the increased mortgage payments, then our customers are saving money each month. What this means in practice is if a higher efficiency home delivers $30/month in bill savings, it still saves customers money monthly for upfront efficiency upgrade costs of up to $7,000.

DTE Supports Michigan's adoption of the 2021 IECC (no amendments): Reduction of Future Peak Demand

Improved building codes provide significant benefits to all DTE customers by reducing summer peak demand impacts of new buildings. DTE is a summer-peaking utility; summer peaks are driven by high air conditioning consumption during summer heat waves. Summer peak capacity needs determine the size requirements (and accompanying system costs) for generation, transmission, and distribution equipment throughout the system. As a result, a significant portion of DTE's cost of service is tied to

[1] Based on MEEA building simulation of 2015 Michigan and 2021 IECC prescriptive prototype homes.

provision of summer peak demand. The avoided cost of supplying 1 kW of demand is currently estimated at approximately $70/kW/year.[2]

With all proposed 2021 code changes adopted, new residential buildings are expected to reduce summer peak demand for a typical new home by 13% compared to existing Michigan code, saving approximately 0.3 kW per home.[3] Each new home will generate about $22 per year in savings for existing home customers of DTE, and over $700 over the next 30 years, over and above the benefits delivered to new home occupants.

DTE Recommends Increasing the Number of Required Additional Efficiency Package Options

The proposed code, based on IECC 2021, introduces the idea of Additional Efficiency Package options, which DTE believes will generate high energy savings at low costs while providing builders with flexibility in complying with a high efficiency code. However, the national code includes an efficiency package for ducts inside conditioned space. In Michigan, where most homes come with basements, almost all homes are currently being built with ducts inside conditioned space. 94% of the 5,000 homes submitted to the DTE New Home Construction program since 2019 have had at least 95% of ducts inside conditioned space.

Because having ducts in conditioned space requirement is a trivial requirement, DTE recommends making an amendment to the proposed code to instead require at least three (3) options be selected from the list of Additional Efficiency Package Options, in keeping with the spirit of what the authors of IECC 2021 were trying to achieve. Because DTE's new home construction program aims to provide incentives for optional additional efficiency package options, the cost of compliance with this provision will be reduced, while generating energy cost savings for customers.

[2] 2021 Michigan Energy Potential Study: 2021 Energy Waste Reduction and Demand Response Statewide Potential Study (michigan.gov)

[3] Based on MEEA building simulation of 2015 Michigan and 2021 IECC prescriptive prototype homes.

AIA Michigan

The American Institute of Architects

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15 March 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
LARA-BCC-Rules@michigan.gov

RE: 10a Michigan Energy Code (ORR# 2021-49 LR)

We are writing in support of including the IECC appendices, specifically Appendix CC, in the Michigan Commercial Building Code. Currently, they are not specifically included in the current draft language, though the ASHRAE appendices are.

IECC 2021 Appendix CC (aka Zero Code) is a flexible framework that cities and states can use to help reach their building decarbonization goals. IECC 2021 Appendix CC combines energy efficiency and renewable energy to support the construction of code-compliant, zero carbon buildings that use clean energy. It applies to new commercial, industrial, and mid- to high-rise residential buildings—the dominant building types being constructed in cities today.

As a VOLUNTARY Appendix, it gives any Authorities Having Jurisdiction the option of adopting the appendix. It does not make the appendix mandatory across the State. This provides jurisdictions an important framework to reach their decarbonization goals, if they choose to adopt the appendix.

In summary, we support Appendix CC because:

- Voluntary for jurisdictions to adopt
- Compliance with 2021 IECC is required
- Sets a minimum renewable energy requirement based on energy simulations or default values
- Provides an incentive for buildings to be designed to be more energy efficient than code requires
- Encourages on-site renewable energy when feasible
- Supports off-site renewable energy procurement when necessary
- 2021 IECC energy efficiency requirements cannot be traded with renewable energy
- Establishes a consistent framework that local governments can modify for their specific needs and conditions

Sincerely,

Cynthia K. Pozolo, FAIA
2022 AIA Michigan President

ANN ARBOR 2030 DISTRICT

16 March 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
LARA-BCC-Rules@michigan.gov

RE: 10a Michigan Energy Code (ORR# 2021-49 LR)

The Ann Arbor 2030 District is writing in support of including the IECC appendices, specifically Appendix CC, in the Michigan Commercial Building Code. Currently, unlike the ASHRAE appendices, they are not specifically included in the current draft language.

IECC 2021 Appendix CC (aka Zero Code) is a flexible framework that cities and states can use to help reach their building decarbonization goals. IECC 2021 Appendix CC combines energy efficiency and renewable energy to support the construction of code-compliant, zero carbon buildings that use clean energy. It applies to new commercial, industrial and mid- to high-rise residential buildings—the dominant building types being constructed in cities today.

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- 2021 IECC energy efficiency requirements cannot be traded with renewable energy
- Establishes a consistent framework that local governments can modify for their specific needs and conditions

All three Michigan 2030 Districts and the AIA are prepared to provide ongoing education for developers, architect, engineers and code officials who are implementing the Zero Code.

Sincerely,

Jan K. Culbertson, FAIA, LEED AP
Leadership Council Chair, Ann Arbor 2030 District

115 1/2 East Liberty
Ann Arbor, MI 48104

a member of the
2030 Districts Network

ZERO Code Renewable Energy Appendix

Code Change Proposal CE264-19; **American Institute of Architects** and **Architecture 2030**
Approved at the Committee Action Hearings, Albuquerque, 2019

July 16, 2019

This code addition is an appendix to the 2021 IECC to require that new commercial, institutional, and mid- to high-rise residential buildings install or procure enough renewable energy to achieve zero-net-carbon annually. The appendix encourages onsite renewable energy systems when feasible, but also supports offsite procurement of renewable energy through a variety of methods. This appendix does not allow renewable energy to be traded off against the energy efficiency required by the 2021 IECC. The provisions contained in this appendix are mandatory when specified as such in the jurisdiction's adopting ordinance.

KEY POINTS

Optional for jurisdictions to adopt

Compliance with 2021 IECC is required

Sets a minimum renewable energy requirement based on energy simulations or default values

Provides an incentive for buildings to be designed to be more energy efficiency than code requires

Encourages onsite renewable energy when feasible

Supports offsite renewable energy procurement when necessary

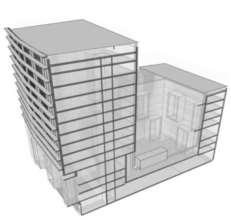
2021 IECC energy efficiency requirements cannot be traded with renewable energy

Establishes a consistent framework that local governments can modify for their specific needs and conditions

MEETING THE CODE

1

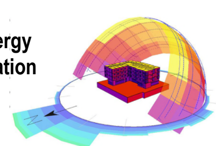
Design an energy efficient building in compliance with the 2021 IECC *or better*.



2

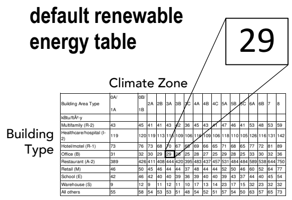
Establish the building's renewable energy requirement from:

an energy simulation



or

default renewable energy table



3

Meet the requirement by integrating onsite renewable energy when feasible.

4

If necessary, procure offsite renewable energy.

Source: Architecture 2030
Graphic adaptations: Sefaira; DOE, Green Ideas

Buildings are required to comply with the 2021 IECC using either the prescriptive or performance approach. When the prescriptive approach is used, the renewable energy required to be installed or procured is specified based on building type and climate zone in Table AX104.1. For instance, an office building in climate zone 3A would need renewable energy production of 29 kBtu/ft2-y. When the performance approach is used, the renewable energy requirement is based on energy modeling and the needed renewable energy can be reduced through energy efficiency measures that exceed code.

The Need

We are already seeing the consequences of 1 °C of global warming through more extreme weather, rising sea levels, rapid biodiversity decline, and diminishing Artic sea ice. At the 2015 Paris accord, 195 nations agreed to a goal of under 2°C (preferably 1.5 °C) of temperature rise. A recent Intergovernmental Panel on Climate Change (IPCC) report warns that to achieve the 1.5 °C goal, we must reduce CO_2 emissions by 45 percent by 2030[1]

Electricity generation is responsible for a large share of CO_2 emissions in the United States.[2] About 75% of the electricity produced is used to power our buildings, so designing them to be energy efficient and then offsetting energy use with non-combustible renewable energy is the most cost effective decarbonization strategy we can take.

States and cities across the country are pursuing policies to address climate change. More than 270 cities and counties and 10 states in the U.S. are signatories to the “We Are Still In” commitment supporting climate action to meet the goals of the Paris climate accord. To date, seventy cities have committed to being powered by 100% renewable energy and more are joining all the time. The ZERO Code Renewable Energy Appendix (ZC_{REA}) provides these communities with a powerful tool and a consistent policy option to accelerate the transition to a 100% clean electric grid. Standardization and consistency will speed the process toward meeting their carbon reduction goals. Manufacturers, builders, designers and others in the building industry will all be operating from the same playbook, as opposed to a patchwork of divergent local approaches that might otherwise emerge.

What makes the ZERO Code Renewable Energy Appendix unique is:

1. ***incorporation into the 2021 IECC***, a highly-efficient national building energy code;
2. ***availability of sophisticated easy-to-use code compliance tools and software*** such as COMcheck, EnergyPlus, and a multitude of private-sector energy performance programs;
3. ***a renewable energy default table and calculator***, for all U.S. locations, that determines the renewable energy required, and estimates the potential on-site renewable energy production and off-site renewable energy procurement needed to achieve zero-net-carbon; and
4. ***recognition of off-site renewable energy options*** that result in renewable energy generation that exceeds what utilities are already required to provide by their mandated renewable portfolio standards.

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1 https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf
2 Energy Information Administration, Annual Energy Outlook, 2018.

Thank you for your time on Tuesday for me to express my concerns with the impact to families in Michigan with the price increase in housing that would be associated with the new code. As our city's housing stock continues to age, the incremental additions to cost over the last couple decades have created a such a disparity in cost between existing stock that makes it almost impossible to get appraisal values to match the cost of a house. As costs grow and housing stock ages without an incremental approach to allow for some type of new housing that is incrementally better than the older existing without building to the highest level of new construction houses will continue to discourage regrowth in our core communities.

A single focus of energy efficiency is short sited and has been a significant attributor to the housing crisis facing the United States today. If the State of Michigan is serious in wanting to make attaining the American Dream of home ownership more accessible, then wholesale changes need to be made to how we think about the process of housing. I would be happy to sit down with anyone who is going to be part of the decision-making process to discuss what the State of Michigan can do to become a leader the national discussion of how we address this critical issue. Thank you again for allowing for input into this process.

Sincerely,
Brent Forsberg
[redacted]

March 16, 2022

Mr. Keith Lambert
Director, Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
611 W Ottawa St.
Lansing, MI 48933

Re: Michigan's 2021 Energy Conservation Code Adoption

Dear Director Lambert,

On behalf of the Ceres Energy Optimization Workgroup, we would like to thank you for soliciting input on Michigan's proposed update to its commercial and residential energy conservation code.

Ceres is a nonprofit sustainability advocacy organization working with the country's most influential companies and investors to build a more sustainable global economy. As part of this work, Ceres manages the BICEP Network, a coalition of nearly 85 major employers, leading consumer brands, and Fortune 500s. It also manages the Energy Optimization Workgroup, a separate workgroup of more than two dozen companies focused on enhancing opportunities for energy efficiency investment at the state and local levels.

Climate change poses a significant risk to the long-term economic success of our members and the larger business community. It threatens the health and livelihood of the communities in which businesses operate and disrupts the value chains on which they rely. Because of these risks, companies in Michigan and nationwide are making significant commitments to reduce their greenhouse gas ("GHG") emissions.

However, businesses are often constrained in how much they can do to drive down their total GHG emissions footprint. For example, their direct ability to optimize the sources of energy that power the economy is limited. Therefore, they have a significant interest in finding ways to systematically improve the emissions performance of our electricity and gas systems, including through the support of policies like building energy codes which eliminate energy waste, reduce peak demand, and support efficient fuel switching.

I. Ceres Supports the Adoption of the 2021 International Energy Conservation Code ***Without*** Weakening Amendments.

Building energy codes establish a new baseline for energy efficiency by setting performance standards for homes and commercial buildings. Updated codes help businesses and residents save money on their utility bills while reducing emissions, improving indoor and outdoor air quality, and spurring innovation in building design and construction. They also spur innovation in the market, creating new jobs and driving economic development in the State.

Codes and standards are some of the most cost-effective ways to reduce the energy use and emissions from our built environment. They are especially important in Michigan because buildings account for more than ~48 percent of all energy consumed in the State.[1]

The energy monitoring provisions in the 2021 IECC establish standards of transparency in building energy usage,[2] which is an important component of any GHG emissions reduction strategy. Energy monitoring also increases awareness of, and engagement with, energy efficiency measures and other energy and emissions savings opportunities. Numerous tools exist to support energy use monitoring (also known as benchmarking), including ENERGY STAR® Portfolio Manager. In fact, almost 25% of commercial square footage is already benchmarked using this free tool.[3]

For all of these reasons, we express our strong support for the adoption of the 2021 International Energy Conservation Code *without* weakening amendments for residential and commercial buildings.

Recent analysis from the U.S. Department of Energy's Pacific Northwest National Laboratory estimates that the adoption of the 2021 IECC by the State would deliver the following financial savings, emissions reductions, and job creation benefits:[4]

- $2.5 billion in energy cost savings over the next 30 years;
- 11,460,000 metric tons of avoided CO_2 emissions over the next 30 years (the equivalent to the annual CO_2 emissions of 6,180,779 cars on the road[5]); and
- The creation of over 6,675 new jobs in the construction sector.

Meanwhile, energy efficient construction decreases the likelihood that a home will default,[6] and thus is a critical tool for building the economic resilience of the communities in which businesses operate.

II. Building Code Provisions for Electric Vehicle (EV)-, Solar-, and Electric-Readiness Enable Consumer Choice

In order to meet Michigan's ambitious climate goals of economy-wide carbon neutrality by 2050 and its interim emissions reductions goal of 52% by 2030 and 28% by 2025, the State must divert investments away from fossil fuels and toward clean, zero-emission technologies.[7] Buildings are responsible for 19.8% of carbon dioxide emissions, which is largely attributable to the use of methane gas for space

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[1] U.S. Energy Information Administration, Michigan Energy Consumption by End-Use Sector, 2019, https://www.eia.gov/state/?sid=MI#tabs-2
[2] Section 405.12 to C405.12.5 applies only to commercial buildings over 25,000 sq. ft.
[3] Benchmark Your Building Using ENERGY STAR® Portfolio Manager® https://www.energystar.gov/buildings/benchmark
[4] U.S. Department of Energy's Pacific Northwest National Laboratory, "Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan," July 2021, https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf
[5] United States Environmental Protection Agency, "Greenhouse Gas Equivalencies Calculator," https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
[6] Institute for Market Transformation, *Home Energy Efficiency and Mortgage Risks*, 2013, http://www.imt.org/uploads/resources/files/IMT_UNC_HomeEEMortgageRisksfinal.pdf
[7] Draft Michigan Healthy Climate Plan, https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf

and water heating.[8] Reducing methane gas use is critical to Michigan's climate change mitigation efforts. In fact, Michigan's draft Healthy Climate Plan[9] encourages several opportunities for electrification and energy savings, recognizing that, "[T]he electrification of Michigan homes and businesses is a promising tool for reducing carbon emissions." The Biden Administration also recently announced a joint goal with the European Union to achieve 30% methane emissions reduction by 2030, relative to 2005 levels.

As a starting point, the incorporation of EV-, solar-, and electric-readiness in new buildings prepares a future-ready building stock that positions Michigan towards its cleaner energy future. Distributed energy resources (DERs) such as EVs and rooftop solar are already economical for many consumers and are an increasingly popular choice in the face of extreme weather, volatile gas prices, and technology innovation. Incorporating DER and electric-readiness into buildings at the outset will avoid unnecessarily costly and time-consuming upgrades for consumers. Indeed, by including these readiness provisions in the energy code, you are ensuring that adoption of EVs, solar, and electrification are as economical as possible, allowing for more consumers to adopt these technologies.

For these reasons, Ceres supports the addition of EV-, solar-, and electric- readiness provisions in the new Michigan code.

III. Incorporating Grid-Connected Technologies for Demand Response Capabilities in the Building Code will Increase Building and Grid Resiliency and Empower Consumers

Smart thermostats and efficiency, grid-connected electric water heaters are cost effective technologies that help shift and shape load profiles, resulting in lower energy bills for consumers, increased building and grid resiliency, and decreased emissions for all. A recent report found that by retrofitting gas water heating systems in existing buildings with grid connected, efficient electric water heaters, consumers could see "energy savings of 85% and greenhouse gas emissions savings of 58%, while providing loadshifting benefits to the electric grid." Smart thermostats have been shown to reduce energy by 10-20%.[10] When coupled with demand response programs, these technologies can drive down GHG emissions even further and provide consumers with opportunities to save even more money while decreasing stress on the electric grid.

We recommend including smart thermostats and efficient, grid-connected electric water heaters in the code to empower consumers and decrease grid and building stress while also decreasing GHG emissions.

IV. Adding Air Quality and Ventilation Standards and Gas Leakage Monitoring Provisions Will Create Healthier & Safer Homes and Businesses

While methane gas may emit fewer GHG gas emissions than other fossil fuel resources, it is still a harmful climate pollutant, releasing GHG emissions and particulate matter that reduce air quality and pose severe risks to public health. When burned inside homes, it releases carbon monoxide, formaldehyde, and other air toxic pollutants and can increase the risk of children experiencing asthma

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[8] U.S. Energy Information Administration: https://www.eia.gov/environment/emissions/state/excel/table4.xlsx
[9] Draft Michigan Healthy Climate Plan, p. 32
[10] ACEEE, Energy Impacts of Smart Home Technologies

symptoms by as much as 42 percent.[11] Improving air quality is not only the right thing to do for public health and for Michigan communities, it also makes economic sense. Fewer instances of respiratory illness, missed days of work and hospitalizations will increase personal disposable income and help reduce the financial pressure on state-funded healthcare programs.

Accordingly, we support including code provisions to improve public health and safety by instituting air quality and ventilation standards and gas leakage monitoring of residential and commercial buildings.

Thank you for your consideration of our comments. Please do not hesitate to reach out if we can provide additional information on how we can work together to ensure safe, affordable, and clean buildings within which Michiganders can live and work.

Sincerely,

Ellen Zuckerman & Maren Mahoney
Ceres Energy Optimization Workgroup

Deana Dennis
Ceres

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[11] Rocky Mountain Institute, Gas Stoves: Health and Air Quality Impacts and Solutions

Mr. Keith Lambert
Director, Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
611 W Ottawa St.
Lansing, MI 48933
LARA-BCC-Rules@michigan.gov

Dear Director Lambert,

The City of Grand Rapids (City) appreciates the opportunity to participate in the Energy Code Rules Advisory meetings and submit written comments to the Bureau of Construction Codes at the Department of Licensing and Regulatory Affairs (LARA) on the State's proposed amendments for the Michigan Energy Code (Energy Code). Recognizing the significant importance of these regulations, the City participated in the development of the 2021 International Energy Conservation Code (IECC) (see attached letter). Mayor Rosalynn Bliss, City Building Inspector Mark Fleet and I worked to educate our staff on the proposed IECC code changes, participated in the voting and engaged in the appeals after the vote.

In 2019, the City adopted our six core values and our Strategic Plan. Two of the City's core values include sustainability and equity and we are using these values to guide our decision making. One of the City's six priorities is Health and Environment, where we desire that the health of all people and the environment are advocated for, protected and enhanced. The first objective of this priority is to reduce carbon emissions and increase climate resiliency. We have worked for decades to reduce the City's energy consumption and greenhouse gas emissions and we are now focused on creating and supporting programs and policies to reduce greenhouse gas emissions from the building and transportation sectors throughout our community.

The City understands the urgent need for the reduction of energy and greenhouse gas emissions (GHG) and that the building and transportation sectors are the two largest sources of GHGs in urban areas. In light of this, we have been working diligently since 2017 to identify equitable solutions to decarbonizing our community building sector. Our journey started when we were one of 12 cities nationwide to be accepted into the three-year Urban Sustainability Directors Network's Zero Cities Project (ZCP). Through the ZCP, we learned that with respect to commercial and residential buildings across the city at the end of 2017:

- We have over 62,000 buildings and 205 million square feet
- 52% of that square footage is single family residential, 32% is commercial and 17% is multifamily residential
- The vast majority of all of our buildings are 20,000 square feet or less, but we do have approximately 500 commercial and 55 multifamily buildings that are larger than 20,000 square feet
- Our top five largest types of commercial buildings by size include: unrefrigerated warehouse, office, college, K-12 schools and retail
- 65% of total building energy consumed is from natural gas and 35% is from electricity
- Our top five most energy intensive building types measured by energy use intensity are: fast food restaurants, supermarkets, hospitals, restaurants and convenience stores
- Building sector GHGs are predominantly emitted from electricity consumption (65% of total building sector GHG emissions) with natural gas accounting for 35% of GHG emissions

- Less than 2% of all commercial buildings in the city are greater than 10,000 square feet, but collectively they account for 42% of building sector GHGs
- By 2050, we expect existing buildings to account for approximately 70% of all building square footage and the remaining 30% to be new construction with nearly all of the new construction being for commercial and multifamily residential buildings
- By 2050, we expect nearly 40% of existing buildings to undergo some type of renovation (small to large renovation)
- By 2050, approximately 30% of total building sector GHGs will be generated and energy consumed by newly constructed buildings

Architecture 2030 evaluated this data and stated that a key takeaway is significant commercial building demolition as well as new multifamily growth will provide an opportunity for replacement with low or zero emissions new construction. Two of Architecture 2030's policy implications include point of renovation policies for energy upgrades have the potential to affect buildings and significantly decrease emissions and the Zero Code provides an opportunity to avoid significant emissions in new commercial construction.

Three of the City's greatest opportunities for reducing building sector energy consumption and GHG generation are outside the City's scope of control and authority: 1) electric grid decarbonization efforts, 2) onsite solar regulations (distributed generation tariffs and legislatively approved caps on distributed solar generation), and 3) State of Michigan energy codes that prohibit local municipalities from requiring greater energy efficiency.

In light of the significant opportunity and responsibility that LARA has with respect to building sector energy consumption and GHG emissions, the City respectfully requests that LARA:

- Maintain 2021 IECC with no weakening amendments for both residential and commercial codes; the U.S. DOE estimates that if Michigan adopts the 2021 IECC, then statewide carbon dioxide emissions will be reduced over 30 years by approximately 11.5 million metric tons
- Preserve the 2021 IECC's energy monitoring requirement for buildings over 25,000 square feet (Section 405.12 to C405.12.5) and strengthen the code by requiring end use monitoring of electric vehicle chargers separate from building operations
- Require EV readiness for both commercial and residential codes to support broader and more affordable EV adoption; New Buildings Institute and RMI estimate that requiring EV-ready buildings will only cost an additional $500 at the time of construction and would eliminate the $1,500 to $3,000 retrofit costs needed at a later date; a degree of ubiquity to the EV charging network is a precursor to mainstream EV adoption, which is necessary considering the transportation sector is the largest source of GHGs in Michigan
- Ensure that the code fully supports electrification of all building types and begin considering what changes across the industry need to take place to support the conversion to a requirement for full all-electric codes including backup onsite energy generation in the event of an electric power grid outage (solar, solar + battery, EV that can be used to power buildings, etc.); consider the significant long-term ramifications of newly constructed buildings that include natural gas infrastructure (onsite health concerns, safety, GHG emissions); retrofitting for electrification after a building has been constructed or undergone a major renovation can be very costly; all-electric homes significantly improve the health of residents, enhance fire safety and reduce

carbon monoxide poisonings; New Buildings Institute and RMI estimate that building an all-electric 2021 code-compliant home reduces upfront costs by 16-27%, largely due to not needing to install gas infrastructure, compared to a currently compliant gas-powered home

- Require increased air monitoring and ventilation for buildings with on-site fossil fuel combustion installed for the commercial and residential codes
- Require the most aggressive insulation (wall, ceiling, floor) reasonable
- Evaluate the costs and benefits of requiring solar ready buildings and where there are minimal upfront cost additions and large retrofit costs, consider requiring solar-ready buildings
- Adopt appendices that provide local municipalities the ability to pass more progressive requirements at the local level

The City of Grand Rapids will continue our equitable decarbonization work at the local level through our recently announced Equitable, Healthy and Zero Carbon Buildings Initiative (E.H.Zero). It is only through a diverse portfolio of actions taken at the federal, state and local levels that we can successfully and expeditiously reduce and hopefully eliminate building and transportation sector greenhouse gas emissions.

In partnership.

Alison Waske Sutter | Sustainability and Performance Management Officer
She/Her/Hers
Office of Sustainability and Performance Management
Executive Office of the City Manager | City of Grand Rapids
300 Monroe Ave NW, Suite 480
Grand Rapids, MI 49503
616.456.3689 Phone
asutter@grcity.us | www.grandrapidsmi.gov

City of Grand Rapids, Michigan
OFFICE OF THE MAYOR

ROSALYNN C. BLISS
MAYOR

January 11, 2021

To: International Code Council Board of Directors

The City of Grand Rapids, Michigan is proud to have participated with more than 1,000 government representatives across the U.S. in voting to improve the 2021 International Energy Conversation Code (IECC) by 10%. The IECC serves as the basis for Michigan's building energy code as it does for nearly every state and because buildings account for nearly 40% of U.S. energy consumption and climate emissions, this vote was extremely important to us. In our Strategic Plan, which was passed in April 2019, we committed to reducing carbon emissions and increasing climate resiliency by reducing the carbon footprint of City operations, working to achieve our 100% renewable energy goal for municipal facilities, and creating and supporting programs and policies to reduce carbon emissions from the building sector throughout the community.

The approved 2021 improvements have the opportunity to reduce millions of tons of carbon while reducing energy bills for tenants, homeowners, local governments and business owners. The City of Grand Rapids is especially interested in the first-ever, ready-made optional appendices that can be adopted by state or local jurisdictions that want to achieve zero energy buildings sooner.

One of our key action steps to achieve our desired outcomes was to fully participate in the IECC voting process. As Mayor, I personally voted, and our Office of Sustainability coordinated very closely with our Building Inspections to ensure all eligible voting members were fully informed on the voting process and issues. The Office of Sustainability evaluated all of the proposed energy efficiency and renewable energy revisions and provided a full overview report of their recommendations to all twelve of our IECC voting members.

During the November meeting, the LTCDP voted to recommend the elimination of the International Energy Conservation Code and that it be replaced with a standard. We are deeply concerned that the International Code Council (ICC) Board of Directors is considering this, and we strongly urge the Board to reject this change. This action would be a major change with significant implications. It would remove a direct mode of participation from local governments who have participated in code development processes for years. The process of developing a standard would remove the final determination of code provisions from the hands of the building safety, code, and qualified governmental professionals who are tasked with implementing its decisions daily, likely shifting to a process more heavily influenced by industry professionals with a vested interest in the content of the standard. The ICC code development process appropriately provides input opportunities to these stakeholders while putting final decisions in the hands of qualified governmental professionals whose jurisdictions must ultimately adopt and enforce the code.

The timing and mode of this conversation is highly concerning. To date, it has been considered with no notification to or consultation with the Governmental Members and Governmental Member Voting Representatives such as our team. We are the individuals and entities that will be most impacted by the change. This change that has been proposed and is under consideration was a surprise. We were dismayed at not having heard about this directly from the ICC with an opportunity to consider and comment. We are concerned this decision may be rushed without governmental members having a chance to express their opinions or the ICC being able to conduct its own research on the implications of the change. There has been limited notice and minimal feedback to date even within the venues in which moving from a code to a standard has been discussed.

We are also concerned that this potential change may create negative long-term impacts on the value of the model code and the ICC. There has not been a public exploration and recognition of all the potential ramifications. In our local and state code development processes, the current ICC committee process is viewed more favorably than standards. Our concerns about our ability to continue to work with the IECC in light of this development is because we would feel the need to conduct a significant amount of additional vetting before leveraging a standard in the way that we do the model code. One of the purposes of being a governmental member of the ICC is to reduce these burdens. In addition, ANSI standards committees are difficult for local governments to participate in because of the competing time commitment. While an ICC standards process may outline participatory pathways for local governments via committees, practically, we are concerned about our ability to participate.

Based on the above, we recommend that this change be rejected outright. Failing that, we request that a public announcement be made regarding the proposal that allows that Governmental Members to weigh in on such a momentous decision via a formal comment period of at least 60 days. Sufficient time is needed to understand the technical, legal and practical implications of this decision. The ICC should outline the technical basis for the standard, the anticipated revision cycle, if the standard will be based on the 2021 IECC, and the criteria for the makeup of the committee that will be advancing the standard before any comment period. Should the ICC move forward with this dramatic elimination of the IECC, we request that the ICC Board publish the result of its vote, including how each board member has voted, and document its reasons for making this change. This would provide needed transparency to governmental members about the process and decision-making.

The IECC is important to our City's policies, impacting the affordability, resilience, sustainability, and safety of our buildings. We see and are working to address the impacts of the energy codes daily. ICC's online voting process allows us to participate more fully in I-Codes and have all of our voices and votes counted in a manner that does not take away from our daily responsibilities.

In support of City of Grand Rapids leadership and transformation efforts, sustainability is a keystone value in all our efforts, especially supporting code changes that support energy conservation in the built environment. We also support ICC leaders, members, and code officials' efforts toward improving codes that affect owners, developers and occupants within the built environment in accordance with currently approved ICC by-laws. We encourage ICC leadership and appeals process to function in accordance with

ICC by-laws and for code development to be for the betterment of humanity. We believe the code is stronger because of the breadth of participants in the process and we look forward to continuing to take part.

Sincerely,

Rosalynn Bliss
Mayor
City of Grand Rapids

Alison Waske Sutter
Sustainability and Performance Management Officer
City of Grand Rapids

Mark Fleet
Building Official
City of Grand Rapids

Greetings.

I am providing comments on the upcoming adoption of Michigan Building Codes being discussed now.

I am an international development professional and have lived and worked in many different U.S. states as well as abroad. My area of expertise is local government service delivery, program design, and governance.

In Michigan current restrictions not allowing local governments to adopt stricter, more energy efficient building codes is holding our state back from economic development and energy savings, decreasing the quality of life for our residents and making our state a low performer in growth and competitiveness.

Holding back municipalities from stricter standards leaves our state with no examples of important innovations, and we are forced to look elsewhere. Leaving decisions up to developers is not sufficient to create the right atmosphere for important improvements.

I worked in Poland for many years after the fall of their centralized government system, which infringed on the right of local government to make its own decisions. The limitations placed on local government in Michigan: not being able to adopt higher energy efficiency standards for buildings, not being able to limit single use plastic, not being able to require accessible housing, etc. hold back ingenuity and local self government. I would think we see our selves as a pro- local self-government state, not one where the state holds back our municipalities from looking to the future and doing the best job they can for their residents.

The traditional argument has been to "level the playing field" in Michigan, but this is a race to the bottom in terms of innovation and experience. And, it sounds a lot like former communist governments in Central Europe - like when I worked in Poland, which held back municipalities for generations.

I look to the language in the State of Maryland, and urge Michigan decision makes to adopt similar language and position to allow local governments to meet or exceed state minimums:

"Each local jurisdiction in Maryland may modify these codes to suit local conditions with exception to the International Energy Conservation Code (IECC - The Energy Code) and Maryland Accessibility Code (MAC - The Accessibility Code). The Energy Code and the Accessibility Code can be made more stringent but not less by the local jurisdictions. Please refer to the local jurisdictions listed under "Local Ordinances and Contacts" to view local ordinances that may contain their modifications. Since ordinances change and are modified from time to time, please contact the local jurisdictions to obtain their current building code information."

We need more autonomy for local decision makers. And, Michigan needs excellent examples of the very best practices in energy saving, building standards, and materials selection - not lots and lots of buildings that only meet minimal standards.

Thank you for considering my comments.

Ann

Ann E. Bueche (Planning Commissioner, City of Royal Oak, Michigan)

Be Kind. (re)Design.
Better Places & Practices for People & the Planet

Inquiry | Analysis | Culture Shift | Baby Steps

[redacted]

[redacted]

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

Dear Director Hawks, Deputy Director Pendleton, and Director Lambert,

Thank you for the opportunity to submit comments about the proposed amendments to the Michigan Energy Code. Clean Fuels Michigan is a nonprofit trade organization advancing the future of clean transportation in Michigan. We advocate for policies and programs that support the transition to cleaner and zero-emission fuels. Our membership is strong and broad, spanning utility companies, auto manufacturers, fleet operators, charging station companies, advocacy groups, and more.

Make-ready infrastructure for electric vehicles is critical

Electric vehicle (EV) make-ready building codes reduce the cost of installing charging stations. Codes can establish requirements for new construction projects to include electrical capacity, conduit, and wiring for the possible installation of EV charging stations in the future.

Car manufacturers across the nation are making commitments to transition their vehicle offerings to electric. General Motors, Ford, Volvo, Jaguar, Honda, Mercedes-Benz, and others expect 100% of their sales to be electric by 2040, and some of them even earlier. The transition to electric vehicles will require charging stations in residences, workplaces, parking lots, and other commercial venues.

The next decade will be a critical time period to build the required infrastructure to re-charge an increasing number of electric cars. The Michigan Energy Code is an opportunity to set Michigan drivers and building owners up for success; future-proof our built environment and to lower the cost of electric vehicle charging equipment.

Studies show that EV infrastructure can cost up to 75% less[1] to install during new construction compared to retrofitting an existing parking lot or building. New residential and commercial buildings are designed to last for decades, so they should be ready to accommodate the upcoming demand for electric vehicle charging infrastructure.

[1] Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report

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www.cleanfuelsmi.org
CleanFuelsMI
CleanFuelsMI
clean-fuels-michigan

Clean Fuels Michigan recommends adding EV readiness language and definitions to the residential code as follows:

Residences, including one- and two-family dwellings and townhouses with a dedicated attached or detached garage or on-site parking spaces, should have at minimum one *EV ready space* per dwelling unit.

EV READY SPACE for residential applications is defined as a designated parking space that is provided with an electrical circuit capable of supporting an installed 208/240-volt circuit level 2 electric vehicle supply equipment (EVSE) within three feet of the proposed location of the EV parking space.

Clean Fuels Michigan recommends adding EV readiness language and definitions to the commercial code as follows:

Parking facilities shall be provided with electric vehicle charging infrastructure in accordance with the table below, based on the total number of parking spaces and rounded up to the nearest whole number. Where more than one parking facility is provided on a building site, the number of parking spaces required shall be calculated separately for each parking facility.

SUGESTED ELECTRIC VEHICLE CHARGING INFRASTRUCTURE REQUIREMENTS

OCCUPANCY	*EV INSTALLED SPACES*	*EV READY SPACES*	*EV CAPABLE SPACES*
Group B Occupancies	15%	NA	40%
Group M Occupancies	25%	NA	40%
R-2 Occupancy	NA	100% (or one per unit)	NA
All other Occupancies	10%	NA	40%

EV Installed, EV ready and *EV capable spaces* may be counted toward meeting minimum parking requirements. *EV Installed spaces* may be used to meet requirements for *EV ready spaces* and *EV capable spaces. EV ready spaces* may be used to meet requirements for *EV capable spaces.*

EV INSTALLED SPACE is a parking space that is provided with a dedicated EVSE. The EVSE serving EV Installed spaces shall be capable of supplying not less than 6.2 kW to an electric vehicle and shall be located within 3 feet (914 mm) of the parking space.

EV READY SPACE is a parking space that is provided with an electrical circuit capable of supporting an installed EVSE. The branch circuit serving *EV Ready Spaces* shall have wiring capable of supporting a 40-amp 208/240-volt circuit and terminate at an outlet or junction box located within 3 feet (914 mm) of the parking space.

EV CAPABLE SPACE is a parking space that is provided with some of the infrastructure necessary for the future installation of an EVSE – such as conduit, raceways, electrical capacity, or signage – or reserved physical space for such infrastructure. *EV Capable Spaces* shall be provided with electrical conduit that is continuous between a junction box or outlet located within 3 feet (914 mm) of the parking space and an electrical panel serving the area of the parking space.

Conclusion and final thoughts

Thank you again for the opportunity to submit comments in the Michigan Energy Code process. These comments are to be interpreted as *minimum suggestions* and do not indicate an unwillingness to support additional electric vehicle readiness requirements. We look forward to working with you to prepare Michigan's buildings for electric vehicles. Please do not hesitate to reach out with any questions.

Sincerely,

Jane McCurry
Executive Director
[redacted]

3/16/2022

LARA-BCC Officials,

Adopting the 2021 International Energy Conservation Code (IECC): Amend Section R406.4

Why adopt the 2021 IECC?

Dream DET supports the State of Michigan adopting the 2021 IECC when considering moving to an updated version of the energy code. The 2021 IECC represents approximately significant energy savings versus the 2015 IECC, and clarifies many aspects of implementation of the code versus the 2015 IECC.

However, there is an important change that Michigan should make when amending the model 2021 as it relates to the R406 Energy Rating Index (ERI) compliance path. **Dream DET recommends that Michigan amend the model 2021 IECC to strike the language in Section R406.4 as it relates to modifying the ERI *Reference Design* ventilation rate.**

Why amend the 2021 IECC?

Dream DET asserts that the amendment to Section R406.4 relating to the *Reference Design* ventilation rate creates unintended consequences for calculating the ERI score.

Section R406.4 changes the ventilation rate for the ERI *Reference Design*, resulting in a ventilation rate that is lower than as is prescribed in ERI calculation standard - ANSI/RESNET/ICC 301-2019. The issue with this change is as follows:

1. The change modified the ERI calculation standard which is referenced in Section R406. ANSI/RESNET/ICC 301-2019 is a published American National Standard, and cannot be amended by the ICC and its voting members.

   Therefore, the change to section R406.4 relating to the *Reference Design* ventilation rate results in a non-conforming ERI calculation with the ANSI standard, and therefore can no longer accurately be referred to as an ERI, but rather, in essence, a “2021 IECC R406 compliance score”.

   While this may seem like semantics, this change is impactful. It unintentionally undermined the intent of using the ANSI/RESNET/ICC 301-2019 standard as the reference standard for calculating the ERI. Additionally, it results in a substantial change to the calculation of ERI scores.

2. The change only modified the ERI *Reference Design* ventilation rate; it did not modify the requirements of ANSI/RESNET/ICC 301-2019 as it relates to the *Rated Design* ventilation rate.

   The *Rated Design* is required per ANSI/RESNET/ICC 301-2019 to comply with the ASHRAE 62.2-2013 ventilation rate, which is often higher than the rate prescribed by R406.4. The result of this discrepancy in ventilation rates for the *Reference Design* and *Rated Design* is that the calculated 2021 IECC R406 compliance scores will almost always be 3-10 points higher than the scores calculated by ANSI/RESNET/ICC 301-2019.

   The reason for the resulting higher scores is because the ERI calculation is an efficiency calculation comparing the *Reference Design* and *Rated Design* for all minimum rated features that impact the energy use and efficiency of a home.

   When Section R406.4 requires the *Reference Design* to have less ventilation airflow than the *Rated Design*, this means that the *Rated Design* is forced by the calculation to use more energy for mechanical ventilation than the *Reference Design*, resulting in reduced efficiency performance versus the *Reference Design* and thus higher scores.

It should be noted that the amendment to R406.4 relating to the *Reference Design* ventilation rate is the only modification made to Section R406 relating to calculating the ERI. Unfortunately, by only changing the ventilation rate for the *Reference Design*, and not the *Rated Design*, this created a significant discrepancy between the two and a resulting significant change to the ERI score calculation.

If Michigan wishes to adopt an energy code that aligns with the national RESNET Home Energy Rating System (HERS) Index system, of which the ERI was modeled after, by adopting the 2021 IECC as written, it will result in the calculated R406 compliance scores being higher than the HERS Index score calculated for the same home. RESNET believes this will create significant confusion for building officials, homebuilders, energy raters and anyone else invested in the energy code.

What to do to preserve the ERI calculation?

If Michigan wishes to preserve the ERI calculation as prescribed by ANSI/RESNET/ICC 301-2019 so that it aligns with the national HERS Index calculation, RESNET recommends amending the model 2021 IECC as follows:

R406.4 Energy Rating Index.

The Energy Rating Index (ERI) shall be determined in accordance with RESNET/ICC 301-2019 ~~except for buildings covered by the *International Residential Code*, the ERI reference design ventilation rate shall be in accordance with Equation 4-2.~~

~~Ventilation rate, CFM = (0.01 × total square foot area of house) + [7.5 × (number of bedrooms + 1)]~~ ~~(Equation 4-2)~~

By amending Section R406.4 as suggested above, the ERI will be required to be calculated per ANSI/RESNET/ICC 301-2014 without any change to ventilation rates. This will result in an ERI score that aligns with the HERS Index calculation, and better represents the energy performance of homes required to comply with the R406 ERI score targets as required by Section R406.5 of the 2019 IECC.

Which ventilation rate requirement is better?

Dream DET acknowledges that the scientific and political discussions regarding the "correct" ventilation rate for residential homes is contentious. Neither Dream DET nor standard ANCI/RESNET/ICC 301-2019 seeks to determine the correct ventilation rate for homes.

At the time ANSI/RESNET/ICC 301-2019 was published, the published American National Standard for *Ventilation and Acceptable Indoor Air Quality in Residential Buildings* was ASHRAE 62.2-2013. Therefore, in order to align with other published ANSI standards, RESNET adopted the ventilation rates prescribed by ASHRAE 62.2-2019. RESNET considers this decision to be procedural, rather than political. RESNET as an organization acknowledges ventilation is important for homes that are built to modern building energy code standards, but is neutral regarding which is the "correct" rate.

Regardless of which rate may be best, the ERI calculation procedure does not set Mandatory Requirements for home ventilation rates, but rather this requirement it set forth in Section R403.6 of the 2021 IECC. The ventilation rate in the ERI procedure does not change or modify any requirement of the energy or building code whatsoever, but rather is used only in the ERI score calculation as required by ANSI/RESNET/301-2019.

DreamDET
Development & Energy Technology

3/16/2022

LARA-BCC Officials,

This letter intends to communicate testimony on the proposed updates to the Michigan energy code from the current amended version based on the 2015 IECC, to a version based on the 2021 IECC. While I support updating the energy code in general, my testimony is focused on one specific area of the 2015 MI energy code that introduced an irrational bias towards the Simulated Performance Alternative (R405) compliance path.

Service water Heating[f, g, h, i]	As proposed Use: same as proposed design	As proposed gal/day = 30 + (10 × N_{br})
Thermal distribution systems	Untested distribution systems: DSE = 0.88 Tested Ducts: Leakage rate to outside conditioned space as specified in Section R403.3.2 Tested duct location: Unconditioned attic Tested duct insulation: in accordance with Section R403.2.1.	Untested distribution systems: DSE from Table R405.5.2(2) Tested ducts: Tested leakage rate to outside conditioned space Duct location: As proposed Duct insulation: As proposed

The MI 2015 energy code Section R405 table R405.5.2(1) outlines the differences between the Proposed Design home (right side of table), versus a Standard Reference Design (left side of table), for the R405 compliance path.

While the language within the MI-amended version of the 2015 IECC is very similar to the model 2015 energy code for this table, the section "Thermal distribution systems" has a critical change that unlocks significant savings for most homes in MI that use the Performance path. In the MI amended version of the code, the thermal distribution system (ie, duct system) for the Reference Home is located 100% in an Unconditioned attic, regardless of the location of the ducts in the Proposed Design.

Given that the majority of homes in MI are built on basements, with ducts substantially located in conditioned space, this one change of the duct system location between the Reference Home and Proposed Design unlocks significant energy savings in the R405 path of code that really is not rational; since most homes are naturally built with ducts substantially located in conditioned space, it doesn't make sense to give homebuilders significant energy savings credit on the Performance Code for locating ducts inside conditioned space.

Thermal distribution systems	Duct insulation: From Section R403.2.1 A thermal distribution system efficiency (DSE) of 0.88 shall be applied to both the heating and cooling system efficiencies for all systems other than tested duct systems. For tested duct systems, the leakage rate shall be 4 cfm (113.3 L/min) per 100 ft^2 (9.29 m^2) of *conditioned floor* area at a pressure of differential of 0.1 inches w.g. (25 Pa).	As tested or as specified in Table R405.5.2(2) if not tested. Duct insulation shall be as proposed.

Above is the same language from the 2015 IECC model energy code. It does not specify a duct location for either the Proposed or Reference Designs, and as such energy modeling software programs consider the location of the ducts to be the same for both the Reference and Proposed Design homes. This makes sense because it neither penalizes nor incentivizes homes to have ducts in a particular location.

In the supporting documentation furnished, I have presented two case studies on the same home design of an actual walkout ranch building plan constructed in Michigan - one is an example of the home built to exact compliance with the Prescriptive UA Tradeoff path of compliance, and the other one is built to near exact compliance with the R405 Performance path.

In the Prescriptive example, this home is modeled at 4 ACH50 infiltration, R-20 above-grade walls, R-10 basement walls, R-10 walkout slab perimeter insulation, R-38 ceilings, and U 0.32 windows per the Prescriptive tables from the code. It precisely meets the UA Tradeoff, as the home is built to the exact specifications of the Prescriptive compliance path. However this home scores 33.2% energy savings on the Performance Path simply due to having the ducts located in conditioned space. There are no other energy savings measures in which this home should be deriving significant energy performance savings.

In the Performance example, the home is modeled at 4 ACH50 infiltration, R-11 above-grade walls, no basement wall insulation, no slab edge insulation, R-19 ceilings, and U 0.32 windows, so a significantly weaker thermal envelope than the Prescriptive approach. As such while the Performance compliance passes by under 1%, this home fails Prescriptive compliance by 73.6%. Again, the only reason this Proposed Design achieves such significant savings that allows for such a weak thermal envelope to still pass code is due to having ducts inside conditioned space, whereas the Reference Home has ducts 100% in an unconditioned attic.

If it were the case that Michigan was a state with a high amount of single-story, slab-on-grade construction, where builders would typically locate ducts 100% in an attic, such as in places like Texas, then it could conceivably make sense to give a performance incentive for builders to locate ducts inside conditioned space by orienting the Simulated Performance Code Reference Design to have ducts 100% in an attic. However, in Michigan, this is not the case; again, the vast majority of homes naturally have ducts largely inside conditioned space due to the predominant basement foundation type.

As a result of this one change to the description of the Reference Home in the R405 table pertaining to duct location, it has enabled homes in Michigan constructed under the 2015 MI amended code to have significantly weaker building thermal envelopes than the Prescriptive path of compliance. Most notably, it has allowed for reduced above-grade wall and foundation wall insulation levels.

Therefore, whatever decision the BCC makes regarding updating the energy code, it must make sure to not recreate this same irrational energy savings issue regarding the Performance Code and duct location in the new version of the code. Again, looking at the example reports, this home built to minimum Prescriptive compliance is projected to have $2633 in energy bills annually, meanwhile the same home built to minimum Performance compliance is projected to cost homeowners $3392 annually, a difference of over $750 per year.

While the Performance path of code offers a valuable method for homebuilders to demonstrate equivalent energy performance to the Prescriptive path through additional infiltration, duct leakage, duct insulation, and mechanical ventilation savings, it should not allow significantly reduced insulation homes to comply with code through irrational savings mechanisms as described above.

Chris McTaggart
Owner
Dream DET

Dream DET
Development & Energy Technology

3/16/2022

LARA BCC officials,

This letter intends to communicate that if the State of Michigan is intending to strike the residential energy provisions of the current amended 2015 IECC, and replace them with potentially amended sections of the 2021 IECC, that the State should do this by rescinding the entire Chapter 4 of the 2015 Michigan Energy code and replacing with the relevant language from the 2021 IECC.

What is currently proposed in the document on LARA-BCC's website, "2021-48 LR Part 10. Michigan Uniform Energy Code (Strike & Bold)", seems to show that only some sections of the Chapter 4 residential energy provisions were rescinded, not all of them. Crucially, this seems to suggest that any item not rescinded from the 2015 Michigan energy code may stay in the updated version of the code based on the 2021 IECC.

The problem with this is that Section R405 the Simulated Performance Alternative – which is very widely used in the state of Michigan - is not marked as being rescinded. The table of performance characteristics between the Proposed Design and Reference Design point to characteristics that come out of the rest of the sections of Chapter 4, such as the insulation tables and airtightness requirements. As such, if you do not rescind Section R405 of the 2015 Michigan energy code as well, then seemingly that would mean that there would be possible discontinuity between what the "old code" prescribes in terms of performance characteristics, and what the "new code" prescribes.

This is fundamentally tied to my other letter regarding the location of "thermal distribution systems" in the current 2015 Michigan energy code that gives unprecedented and significant credit to homes for having ductwork inside conditioned space. If Section R405 is not stricken from the current code, then that would suggest that it is possible that this irrational savings function in the 2015 Michigan energy code may live on, and continue to provide a vehicle for significantly reduced building envelope performance for homes constructed in the State of Michigan.

Additionally, there are other sections of Chapter 4 that do not appear to be rescinded where there are somewhat significant improvements embedded in the 2021 IECC. Specifically, Section R403 Systems has some important updates regarding duct leakage testing, as well as updates to requirements for Mechanical Ventilation that would require such systems to be tested to ensure they are meeting their design airflow. Section R404 includes important provisions regarding high-efficacy lighting.

Dream DET recommends that the State of Michigan rescind the entire Section R401 through Section R406, and replace with the relevant updated language from the 2021 IECC.

Chris McTaggart
Owner
Dream DET

chris@dreamDET.com www.dreamDET.com 248-910-4532

Michigan 2015 Performance Compliance

[redacted]

MI performance example

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

This report is based on a proposed design and does not confirm field enforcement of design elements.

Annual Energy Cost

Design	Michigan 2015 Performance	As Designed
Heating	$1,819	$1,884
Cooling	$299	$212
Water Heating	$230	$230
SubTotal - Used to determine compliance	**$2,348**	**$2,327**
Lights & Appliances	$1,074	$1,065
Onsite generation	$0	$0
Total	**$3,423**	**$3,392**

Requirements

✓	405.3	Performance-based compliance passes by 0.9%
✓	R402.5	Area-weighted average fenestration SHGC
✓	R402.5	Area-weighted average fenestration U-Factor
✓	403.2.2	Duct Testing
✓	R404.1	Lighting Equipment Efficiency
✓	Mandatory Checklist	Mandatory code requirements that are not checked by Ekotrope must be met.
✓	R405.2	Duct Insulation

Design exceeds requirements for Michigan 2015 Performance compliance by 0.9%.

As a 3rd party extension of the code jurisdiction utilizing these reports, I certify that this energy code compliance document has been created in accordance with the requirements of Chapter 4 of the adopted International Energy Conservation Code based on LIVINGSTON County. If rating is Projected, I certify that the building design described herein is consistent with the building plans, specifications, and other calculations submitted with the permit application. If rating is Confirmed, I certify that the address referenced above has been inspected/tested and that the mandatory provisions of the IECC have been installed to meet or exceed the intent of the IECC or will be verified as such by another party.

Name: Chris McTaggart

Organization: Dream Development & Energy Technology, LLC

Signature:

Date: 3/15/22 at 8:18 PM

Michigan 2015 UA Compliance

Property
[redacted]
MI performance example

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

This report is based on a proposed design and does not confirm field enforcement of design elements.

Building UA

Elements	IECC Reference	As Designed
Ceilings	74.9	133.8
Above-Grade Walls	134.4	201.2
Windows, Doors and Skylights	161.2	158.4
Slab Floor:	80.0	90.2
Framed Floors	0.0	0.0
Foundation Walls	70.6	324.5
Rim Joists	10.1	14.2
Overall UA (Design must be equal or lower):	**531.2**	**922.3**

Requirements

402.1.5	Total UA alternative compliance fails by 73.6%.	Specified envelope UA is 922 BTU / hF. This exceeds the maximum of 531 BTU / hF by 73.6%.
402.3.2		
R402.4.1.2	Air Leakage Testing	Air sealing is 4.00 ACH at 50 Pa. It must not exceed 4.00 ACH at 50 Pa.
R402.5	Area-weighted average fenestration SHGC	
R402.5	Area-weighted average fenestration U-Factor	
403.2.2	Duct Testing	
R404.1	Lighting Equipment Efficiency	
Mandatory Checklist	Mandatory code requirements that are not checked by Ekotrope must be met.	

Design fails to meet the requirement for Michigan 2015 Prescriptive compliance by 73.6%.

Name: Chris McTaggart
Organization: Dream Development & Energy Technology, LLC
Signature:
Date: 3/15/22 at 8:18 PM

Building Specification Summary

Property

[redacted]

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

Building Information

Conditioned Area [ft²]	4,550.00
Conditioned Volume [ft³]	42,770.00
Thermal Boundary Area [ft²]	9,056.80
Number Of Bedrooms	4
Housing Type	Single family detached

Rating

HERS Index	71
HERS Index w/o PV	71

Building Shell

Ceiling w/ Attic	A19(24/3.5)(1)BC8; U-0.054
Vaulted Ceiling	None
Above Grade Walls	11(16/3.5)1(.5) adiabatic; U-0.085
Found. Walls	Uninsulated; R-0
Framed Floors	None
Slabs	Uninsulated; R-0

Windows (largest)	U-Value: 0.32, SHGC: 0.45
Window / Wall Ratio	0.16
Infiltration	4 ACH50
Duct Lkg to Outside	0 CFM @ 25Pa (0 / 100 ft²)
Total Duct Leakage	502 CFM @ 25Pa (Post-Construction)

Mechanical Systems

Heating	Furnace • Natural Gas • 96.1 AFUE
Cooling	Air Conditioner • Electric • 13 SEER
Water Heating	Residential Water Heater • Natural Gas • 0.93 Energy Factor
Programmable Thermostat	Yes
Ventilation System	83 CFM • 29.05 Watts (Default)

Lights and Appliances

Percent Interior LED	95%
Percent Exterior LED	100%
Refrigerator (kWh/yr)	950.0
Dishwasher Efficiency	270 kWh
Ceiling Fan (CFM/Watt)	120.0

Clothes Dryer Fuel	Natural Gas
Clothes Dryer CEF	2.3
Clothes Washer LER (kWh/yr)	704.0
Clothes Washer Capacity	2.9
Range/Oven Fuel	Natural Gas

Michigan 2015 Performance Compliance

[redacted]

MI prescriptive example

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

This report is based on a proposed design and does not confirm field enforcement of design elements.

Annual Energy Cost

Design	Michigan 2015 Performance	As Designed
Heating	$1,819	$1,094
Cooling	$299	$243
Water Heating	$230	$230
SubTotal - Used to determine compliance	**$2,348**	**$1,568**
Lights & Appliances	$1,074	$1,065
Onsite generation	$0	$0
Total	**$3,423**	**$2,633**

Requirements

✓	405.3	Performance-based compliance passes by 33.2%
✓	R402.5	Area-weighted average fenestration SHGC
✓	R402.5	Area-weighted average fenestration U-Factor
✓	403.2.2	Duct Testing
✓	R404.1	Lighting Equipment Efficiency
✓	Mandatory Checklist	Mandatory code requirements that are not checked by Ekotrope must be met.
✓	R405.2	Duct Insulation

Design exceeds requirements for Michigan 2015 Performance compliance by 33.2%.

As a 3rd party extension of the code jurisdiction utilizing these reports, I certify that this energy code compliance document has been created in accordance with the requirements of Chapter 4 of the adopted International Energy Conservation Code based on LIVINGSTON County. If rating is Projected, I certify that the building design described herein is consistent with the building plans, specifications, and other calculations submitted with the permit application. If rating is Confirmed, I certify that the address referenced above has been inspected/tested and that the mandatory provisions of the IECC have been installed to meet or exceed the intent of the IECC or will be verified as such by another party.

Name: Chris McTaggart

Organization: Dream Development & Energy Technology, LLC

Signature:

Date: 3/15/22 at 8:40 PM

Michigan 2015 UA Compliance

[redacted]

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

This report is based on a proposed design and does not confirm field enforcement of design elements.

Building UA

Elements	IECC Reference	As Designed
Ceilings	74.9	74.0
Above-Grade Walls	134.4	134.8
Windows, Doors and Skylights	161.2	158.4
Slab Floor:	80.0	80.0
Framed Floors	0.0	0.0
Foundation Walls	70.6	76.5
Rim Joists	10.1	7.4
Overall UA (Design must be equal or lower):	**531.2**	**531.1**

Requirements

✓	402.1.5	Total UA alternative compliance passes by 0.0%.		
✓	402.3.2			
✓	R402.4.1.2	Air Leakage Testing	Air sealing is 4.00 ACH at 50 Pa. It must not exceed 4.00 ACH at 50 Pa.	
✓	R402.5	Area-weighted average fenestration SHGC		
✓	R402.5	Area-weighted average fenestration U-Factor		
✓	403.2.2	Duct Testing		
✓	R404.1	Lighting Equipment Efficiency		
✓	Mandatory Checklist	Mandatory code requirements that are not checked by Ekotrope must be met.		

Design exceeds requirements for Michigan 2015 Prescriptive compliance by 0%.

Name: Chris McTaggart
Signature:
Organization: Dream Development & Energy Technology, LLC
Date: 3/15/22 at 8:40 PM

Building Specification Summary

Property

[redacted]

Organization
Dream Development & En
Chris McTaggart

Builder

Inspection Status
Results are projected

Building Information

Conditioned Area [ft²]	4,550.00
Conditioned Volume [ft³]	42,770.00
Thermal Boundary Area [ft²]	9,056.80
Number Of Bedrooms	4
Housing Type	Single family detached

Rating

HERS Index	55
HERS Index w/o PV	55

Building Shell

Ceiling w/ Attic	A 38FB1(24/11.5); U-0.03
Vaulted Ceiling	None
Above Grade Walls	20FB1(16/5.5) (ambient); U-0.057
Found. Walls	10; R-10
Framed Floors	None
Slabs	R-10 Perimeter; R-10

Windows (largest)	U-Value: 0.32, SHGC: 0.4
Window / Wall Ratio	0.16
Infiltration	4 ACH50
Duct Lkg to Outside	0 CFM @ 25Pa (0 / 100 ft²)
Total Duct Leakage	502 CFM @ 25Pa (Post-Construction)

Mechanical Systems

Heating	Furnace • Natural Gas • 96.1 AFUE
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Percent Interior LED	95%
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Clothes Dryer Fuel	Natural Gas
Clothes Dryer CEF	2.3
Clothes Washer LER (kWh/yr)	704.0
Clothes Washer Capacity	2.9
Range/Oven Fuel	Natural Gas

HOME BUILDERS ASSOCIATION OF MICHIGAN

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Jason Orvosh
Immediate Past President

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Chief Executive Officer

6427 Centurion Drive
Suite 100
Lansing, MI 48917
(517) 322-0224
hbaofmichigan.com

March 16, 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

RE: Proposed Rule Set ORR# 2021-48 LR (Part 10 Michigan Energy Code)

Please accept this letter and attachments in response to the Department of Licensing and Regulatory Affairs, Bureau of Construction Codes call for public comment in its "Notice of Public Advisory Meeting" dated March 1, 2022.

The Home Builders Association of Michigan (HBAM) is the largest statewide trade association representing the residential construction industry. On behalf of our 5000+ members and 20 affiliated local home builders' associations, the attached material is submitted in relation to proposed rule set ORR# 2021-48 LR.

HBAM requests careful consideration of the attached reports as LARA officials contemplate the cost-effectiveness of adoption of an unamended version of the 2021 International Energy Conservation Code (IECC).

Sincerely,

Robert Filka
CEO

Attachments:

- Home Innovation Research Labs 2021 IECC Residential Cost Effectiveness Analysis
- Cost Effectiveness of the Residential Provisions of the 2021 IECC (ICF study)
- Home Innovation Response to ICF Comments Regarding 2021 IECC Residential Cost Effectiveness Analysis
- NAHB Priced-Out Estimates for 2022

Home Innovation
RESEARCH LABS™

2021 IECC Residential Cost Effectiveness Analysis

Prepared For

National Association of Home Builders

June 2021

Report No. CR1391_06112021

400 Prince George's Blvd. | Upper Marlboro, MD 20774 | 800.638.8556 | HomeInnovation.com

TABLE OF CONTENTS

ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

AC	Air Conditioner
AFUE	Annual Fuel Utilization Efficiency
c.i.	Continuous Insulation
COP	Coefficient of Performance
CZ	Climate Zone
EA	Each
EF	Energy Factor
ERI	Energy Rating Index
GF	Gas Furnace
HP	Heat Pump
HPWH	Heat Pump Water Heater
HSPF	Heating Seasonal Performance Factor
IECC	International Energy Conservation Code
IRC	International Residential Code
LF	Linear Feet
O&P	Overhead and Profit
SEER	Seasonal Energy Efficiency Ratio
SF	Square Feet
UEF	Uniform Energy Factor
WH	Water Heater

BACKGROUND

The 2021 International Energy Conservation Code (IECC) includes several changes which impact both energy savings and construction costs for residential construction.

The objective of this analysis is to quantify the incremental construction cost and energy use cost savings associated with constructing a house compliant with the 2021 IECC relative to a 2018 IECC baseline and to evaluate the cost-effectiveness of the code changes.

METHODOLOGY

To evaluate the cost effectiveness of the 2021 IECC changes, Home Innovation Research Labs (Home Innovation) determined incremental construction costs and energy use costs using a Standard Reference House with multiple configurations and in multiple locations, constructed in accordance with the prescriptive compliance requirements of the 2018 IECC and 2021 IECC Residential Provisions ("Sections R401 through R404" in the 2018 IECC; "Prescriptive Compliance Option" in the 2021 IECC). The results provided a basis for estimating energy use savings and simple paybacks.

The analysis for this study is based on a methodology[1] developed by Home Innovation (formerly NAHB Research Center) to calculate energy savings. This methodology defined a Standard Reference House, including the building configuration and energy performance parameters, that was originally used to report an analysis of the 2012 IECC code changes[2].

For analysis in this report, annual energy use costs were developed using BEopt[3] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency[4]. The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas.

Construction costs were developed based on RSMeans[5] 2021 Residential Cost Data. Costs for mechanical equipment were sourced from distributor web sites. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of fees on rater web sites. Cost details are provided for individual code changes in Appendix A and by climate zone in Appendix B.

Appendix A costs are reported as both total to the builder and total to consumer. The total cost to builder includes overhead and profit (designated in the tables as "w/O&P") applied to individual component costs (materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on applying a builder's gross profit margin of 19.0% to the builder's total cost[6]. These represent national average costs. For specific locations, the Appendix A costs could be

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[1] Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.

[2] 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.

[3] BEopt (Building Energy Optimization Tool) software: https://beopt.nrel.gov/home

[4] Energy Information Agency: https://www.eia.gov/

[5] RSMeans, https://www.rsmeans.com/

[6] Industry average gross profit margin for 2017, as reported in NAHB's Builder's Cost of Doing Business Study, 2019 Edition. https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

modified by applying the appropriate location adjustment factor from RSMeans; selected location adjustment factors from RSMeans are listed in Appendix C.

Standard Reference House

The building geometry (Figure 1) used in this analysis is documented in the methodology paper and was originally developed using Home Innovation's 2009 Annual Builder Practices Survey (ABPS) for a representative single-family detached home. The parameters represent the average values from the ABPS for building areas and features not dictated by the IECC. The geometry has been updated based on Home Innovation's 2019 ABPS. Table 1 shows the floor, attic, wall, and window areas used in the Standard Reference House for this study.

Table 1. Average Wall and Floor Areas of the Reference House

Reference House Component	Area (SF)
1st floor conditioned floor area (CFA)	1,875
2nd floor CFA	625
Total CFA without conditioned basement	2,500
Foundation perimeter, linear feet (LF)	200 LF
Slab/basement/crawl floor area	1,875
Total CFA with conditioned basement	4,375
Ceiling area adjacent to vented attic	1,875
1st floor gross wall area (9' height)	1,800
2nd floor gross wall area (8.75' height)	875
Total above grade wall area (excludes rim areas)	2,675
Basement wall area (8' height; 2' above grade)	1,600
Crawlspace wall area (4' height; 2' above grade)	800
Window area (15% of CFA above grade)	375

Figure 1. Simulation Model of Standard Reference House

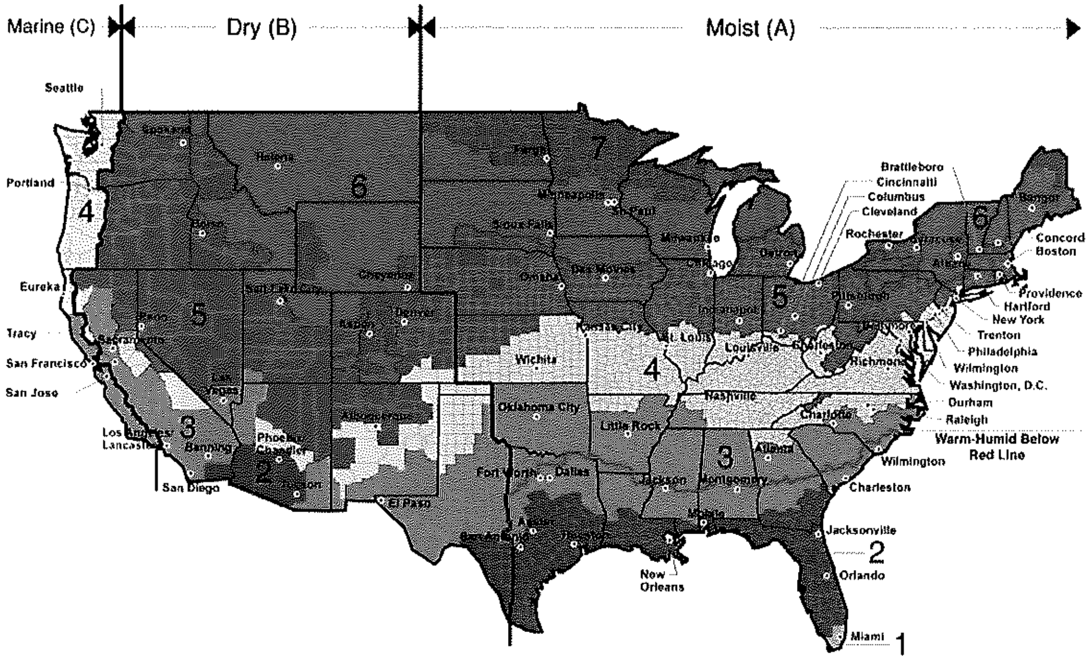
Representative Locations

Six cities (Table 2) representing DOE Climate Zones 2 through 7 (Figure 2) were selected to quantify energy savings for their respective climates.

Table 2. Representative Locations

Climate Zone	2	3	4	5	6	7
City	Phoenix	Memphis	Baltimore	Chicago	Helena	Duluth
State	Arizona	Tennessee	Maryland	Illinois	Montana	Minnesota
Moisture Region	Dry	Moist	Moist	Moist	Dry	N/A
HDD65*	1,050	2,960	4,600	6,330	7,660	9,570
CDD65*	4,640	2,110	1,233	842	317	162

*Daily Average Weather Data (TMY). Source: Residential Energy Dynamics, redcalc.com



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Figure 2. DOE Climate Zone Map

Configurations and Weighted Averaging

Weighted averaging was applied both within and across climate zones based on market statistics for new single-family detached homes as reported by the 2019 ABPS. Within climate zones, weight factors were applied for wall types (light-framed and mass walls) and foundation types (slab, basement, and crawlspace).

The heating fuel used for this analysis, either natural gas or electric, was selected based on the predominant heating fuel in each climate. The predominant fuel for heating is also used for domestic hot water. All other appliances are electric.

Once the costs within a climate zone were determined, a weighted calculation according to housing starts for each climate zone was performed to obtain a national average across climate zones. Weighting averages used for this analysis are shown in Table 3.

Table 3. Construction Data. Source: adapted from Home Innovation's 2019 ABPS

Component	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Primary heating fuel	Electric	Electric	Nat Gas	Nat Gas	Nat Gas	Nat Gas
Mass Wall	30%	10%				
Frame Wall	70%	90%	100%	100%	100%	100%
Slab Foundation	100%	75%	20%	15%	5%	30%
Basement Foundation, finished		10%	60%	70%	90%	5%
Crawlspace, vented		15%	20%			
Crawlspace, conditioned				15%	5%	65%
Housing Starts	28%	28%	21%	17%	5%	1%

HVAC and Water Heating Equipment

The Reference Houses utilize federal minimum efficiency HVAC systems and water heaters as shown in Table 4, except where the 2021 IECC houses are evaluated separately with higher efficiency equipment options suitable for the climate as shown in Table 5.

High efficiency HVAC systems for electric houses consist of air-source heat pump systems (i.e., not ground source or geothermal systems) with variable speed compressors ("inverter" drive compressors that provide variable refrigerant flow). The inverter systems are generally required to meet the minimum HSPF requirement for the heat pump efficiency option for 2021 (10 HSPF/16 SEER; see next section for description of 2021 efficiency package options). In addition to higher efficiencies, inverter systems are considered more suitable for colder climates because these can ramp up to provide higher heating capacities at lower outdoor temperatures compared to typical single-stage or two-stage equipment.

High efficiency water heaters for electric houses consist of heat pump water heater, 50 gallon capacity, 2.0 EF[7]

Table 4. Standard Efficiency Equipment

Reference House	Equipment
Gas	80 AFUE gas furnace + 13 SEER air conditioner (CZ 5-7) or 14 SEER (CZ 4)
	40 gallon gas natural draft water heater, 0.58 UEF
Electric	14 SEER/8.2 HSPF air source heat pump
	50 gallon electric water heater, 0.92 UEF

Table 5. High Efficiency Equipment Options

Reference House	Equipment
Gas	95 AFUE gas furnace + 16 SEER air conditioner
	Tankless gas direct vent water heater, 0.82 UEF
Electric	16 SEER/10 HSPF inverter heat pump, rated to 7°F (CZ 2-3) or -13°F (CZ 5)
	Heat pump water heater, 50 gal, 2.0 EF

[7] UEF (Uniform Energy Factor) is the current measure of water heater overall efficiency; the higher the UEF value, the more efficient the water heater; UEF is determined by the Department of Energy's test method outlined in 10 CFR Part 430, Subpart B, Appendix E.

Changes for 2021

There are significant changes in the 2021 IECC compared to the 2018 IECC that impact construction cost and energy use cost. Changes to the prescriptive insulation and fenestration requirements include increased ceiling insulation (CZ 2-8), increased continuous insulation on frame walls (CZ 4-5), increased slab insulation (CZ 3-5), and lower window U-factor (CZ 3-4); these changes are shown in Appendix D.

Additional requirements include changes for lighting efficiency and controls; additional air sealing; duct testing even if ducts are entirely inside conditioned space; increased fan efficacy and testing for whole-dwelling ventilation fans; installing an HRV or ERV in CZ 7-8.

The 2021 IECC also has a new section that establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency (R401.2.5 Additional energy efficiency). The prescriptive approach requires installing one of the five prescribed additional efficiency package options:

- Enhanced envelope performance (5% improvement of UA and SHGC)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER air source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met; houses in CZ 2 were also modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50).

For houses that already meet the requirements for the efficient duct option (e.g., ducts and air handlers located entirely inside conditioned space) or efficient ventilation/improved air sealing option (e.g., HRV or ERV is now required in CZ 7), no additional efficiency package is required; otherwise, one of the efficiency packages must be selected at additional cost. For this study, the methodology defines houses with basement and conditioned crawlspace foundations as having ducts and air handlers inside conditioned space, and houses with slab and vented crawlspace foundatons as having some ducts outside of conditioned space. Therefore, only houses with slab and vented crawlspace foundations were evaluated for the efficient duct option.

The enhanced envelope option was not evaluted for this study due to it is not considered a reasonably viable option for builders at this time.

For the 2021 IECC, 10 code changes were identified that are considered to have a direct impact on energy use in residential buildings, for a sufficient number of new homes, and which can be reasonably quantified in estimating energy impact. Those 10 changes were included in the energy modeling and are identified in Table 6 with an asterisk.

RESULTS

Construction Costs

The incremental construction costs for the individual code changes that were selected to be evaluated for this study are summarized in Table 6. The cost details are provided in Appendix A for individual changes; Appendix B shows costs by climate zone. The weighted averages of construction costs are shown in Table 7. Changes that represent potential additional construction costs that may or may not affect the Reference House are shown separately in Table 8.

Table 6. Incremental Construction Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE7*	Lighting: revised definition of high-efficacy	All	$0
RE18/20/21	Certificate: additional info	All	$99
RE29*	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970
RE32*	Slab edge: NR to R10/2 (CZ3)	3	$1,988
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993
RE33*	Ceiling insulation R38 to R49	2-3	$1,366
RE36*	Ceiling insulation R49 to R60	4-7	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA
RE35*	Windows: reduces U-value from 0.32 to 0.30	3-4	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13
RE49	Baffles at attic access	All	$12
RE72	Air seal narrow framing cavities	All	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417
RE96	House tightness, allows trade-off for performance path	All	$0
RE103	Air seal electrical & communication outlet boxes	All	$369
RE106	Thermostat: requires 7-day programming	All	$0
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62
RE133*	Updates ventilation fan efficacy (affects bath EF)	All	$66
RE139*	Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.)	7	$3,206
RE145*	Lighting: 100% high-efficacy; controls (slab)	All	$49
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60
RE148	Lighting, commercial	All	NA
RE149	Lighting: exterior controls	All	$25
RE151	Performance path backstop: 2009 IECC	All	NA
RE178	Performance path ventilation type to match proposed	All	NA
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA

RE209*	<u>Additional efficiency package options:</u>	All	
	HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline	5-7	$1,494
	HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline	4	$1,317
	HVAC, electric house, 10 HSPF/18 SEER heat pump rated to 7F	2-3	$5,721
	HVAC, electric house, 10 HSPF/16 SEER (10/18, rated -13F)	5	$8,196
	Water Heater, gas house, tankless direct-vent, 0.82 UEF	All	$740
	Heat Pump Water Heater, electric house, 50 gal, 2.0 EF	2-3	$1,331
	Ventilation, gas house	4-7	$3,206
	Ventilation, electric house	3-5	$3,109
	Ventilation, electric house with improved air tightness	2	$4,591
	Duct, slab house, buried ducts in attic	2-3	$4,125
	Duct, slab house, buried ducts in attic	4-7	$1,736
	Duct, vented crawlspace house	3	($852)
	Duct, vented crawlspace house	4	($193)

*Indicates a code change that was included in the energy modeling analysis for this study (10 total)

Table 7. Incremental Construction Cost for 2021 Reference House, weighted averages

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Total without additional efficiency package options	$5,477	$2,648	$4,326	$8,550	$8,695	$3,685	$6,618
Total with HVAC option	$9,301	$8,369	$10,047	$9,867	$10,188	$5,179	$8,112
Total with Water Heater option	$6,548	$3,979	$5,657	$9,290	$9,435	$4,426	$7,358
Total with Ventilation option	$9,011	$7,238	$7,435	$11,755	$11,900	$6,891	$6,618
Total with Duct option, slab house	$8,550	$6,773	$8,451	$10,286	$10,431	$5,421	$8,354
Total with Duct option, vented crawlspace house			$3,474	$8,356			

Table 8. Potential Additional Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE47	Attic pull-down stair: adds exception to insulation requirements	2-3	($90)
	Same	4	($119)
RE49	Baffles at tray ceiling (example)	2-3	$183
	Same	4-7	$231
RE52	Walls: removes exception for reduced c.i. at WSP	3-7	$640-$2,652
RE55	Adds requirements for unconditioned basements	4-5	$59
RE109	Floor insulation for ducts in conditioned space: min R19	2	$87
RE134	Adds min efficacy for air handlers if integrated w/ventilation	All	$1,222

Energy Use Costs and Savings

The modeling results for annual energy use costs are shown in Table 9. The estimated energy savings, as a percentage of energy use costs, are shown in Table 10. The values shown in Table 9 and Table 10 are weighted averages; energy use details are provided in Appendix E.

Cost Effectiveness

The construction costs (Table 7) and annual energy use costs (Table 9) provide the basis to calculate simple paybacks, shown in Table 11.

Table 9. Annual Energy Use Cost for Reference House, weighted averages

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,129	$2,224	$2,027	$1,934	$2,280	$2,388	$2,599
slab houses only	$2,074	$2,224	$2,024	$1,807	$2,156	$2,221	$2,735
vented crawl houses only			$1,959	$1,826			
2021 without additional efficiency package options	$2,016	$2,163	$1,890	$1,797	$2,137	$2,310	$2,514
2021 with HVAC option	$1,882	$2,045	$1,768	$1,680	$1,959	$2,113	$2,266
2021 with Water Heater option	$1,922	$2,028	$1,741	$1,761	$2,106	$2,283	$2,505
2021 with Ventilation option	$1,994	$2,144	$1,876	$1,778	$2,104	$2,251	$2,495
2021 with Duct option, slab house	$1,851	$2,046	$1,789	$1,585	$1,889	$1,985	$2,418
2021 with Duct option, vented crawlspace house			$1,845	$1,644			

Table 10. Energy Cost Savings relative to 2018 Baseline Reference House

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	5.3%	2.7%	6.8%	7.1%	6.3%	3.3%	3.3%
2021 with HVAC option	11.6%	8.0%	12.8%	13.1%	14.1%	11.5%	12.8%
2021 with Water Heater option	9.7%	8.8%	14.1%	8.9%	7.7%	4.4%	3.6%
2021 with Ventilation option	6.4%	3.6%	7.5%	8.1%	7.7%	5.7%	na
2021 with Duct option, slab house	10.7%	8.0%	11.6%	12.3%	12.4%	10.6%	11.6%
2021 with Duct option, vented crawlspace house			5.8%	10.0%			

Table 11. Simple Payback relative to 2018 Baseline Reference House, years

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	48	43	31	62	61	47	78
2021 with HVAC option	38	47	39	39	32	19	24
2021 with Water Heater option	32	20	20	54	54	42	79
2021 with Ventilation option	67	90	49	75	68	50	63
2021 with Duct option, slab house	38	38	36	46	39	23	26
2021 with Duct option, vented crawlspace house			30	46			

As mentioned in the Methodology section, houses were evaluated based on using either natural gas or electricity as the fuel for heating and hot water: electric in CZ 2-3; gas in CZ 4-7. To illustrate the difference in energy savings for comparison purposes by way of an example, houses in CZ 3 were also modeled using gas, and sample results are shown in Table 12. For houses with the water heater option, the energy savings decreased from 14.1% for electric houses (from Table 10) to 9.9% for gas houses, with a weighted average of 12.2%; the national average energy savings decreased from 9.7% (from Table 10) to 9.3%.

Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline

	CZ 3 Memphis			National
Configuration	Electric	Gas	Weighted Ave*	Average
2021 without additional efficiency package options	6.8%	7.6%	7.1%	5.5%
2021 with Water Heater option	14.1%	9.9%	12.2%	9.3%

*Weighted average based on 55% electric houses and 45% gas houses, adapted from ABPS

Cost Effectiveness of Selected Code Changes

Individual code changes were selected for evaluation. The results are shown by applicable climate zone for thermal envelope changes in Tables 13 through 16, the required HRV in CZ 7 in Table 17, and the additional efficiency package options in Tables 18 through 21.

Table 13. Incremental Construction Cost of Thermal Envelope Changes

Component	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Ceiling insulation	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
Slab insulation		$1,988	$993	$993		
Wall continuous insulation			$4,970	$4,970		
Window U-factor		$76	$76			

Table 14. Annual Energy Use Cost of Thermal Envelope Changes

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,224	$2,027	$1,934	$2,280	$2,388	$2,599
2018 baseline, slab houses only		$2,024	$1,807	$2,156		
2018 + 2021 ceiling insulation	$2,216	$2,016	$1,925	$2,268	$2,376	$2,584
2018 + 2021 slab insulation, slab houses only		$1,936	$1,772	$2,120		
2018 + 2021 wall continuous insulation			$1,886	$2,217		
2018 + 2021 window U-factor		$2,020	$1,924			

Table 15. Energy Cost Savings of Thermal Envelope Changes relative to 2018 Baseline Reference House

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	0.3%	0.6%	0.5%	0.5%	0.5%	0.6%
2018 + 2021 slab insulation, slab houses only		4.3%	1.9%	1.7%		
2018 + 2021 wall continuous insulation			2.5%	2.8%		
2018 + 2021 window U-factor		0.3%	0.5%			

Table 16. Simple Payback relative to 2018 Baseline Reference House for Thermal Envelope Changes, years

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	177	122	152	118	105	90
2018 + 2021 slab insulation, slab houses only		23	28	28		
2018 + 2021 wall continuous insulation			103	78		
2018 + 2021 window U-factor		11	7			

Table 17. Cost effectiveness of HRV in CZ 7

Configuration	CZ 7 Duluth
Incremental cost of HRV	$3,206
Annual energy cost, 2021* without HRV	$2,538
Annual energy cost, 2021* with HRV	$2,514
Energy cost savings for HRV	1.0%
Simple payback, years	131

*Without additional efficiency package options

Table 18. Incremental Construction Cost of Additional Efficiency Package Options

Component	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	$5,721	$5,721	$1,317	$1,494	$1,494	$1,494
Water heater option	$1,331	$1,331	$740	$740	$740	$740
Ventilation option	$4,591	$3,109	$3,206	$3,206	$3,206	
Duct option, slab house	$4,125	$4,125	$1,736	$1,736	$1,736	$1,736
Duct option, vented crawlspace house		($852)	($193)			

Table 19. Annual Energy Use Cost of Additional Efficiency Package Options

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options, all houses	$2,163	$1,890	$1,797	$2,137	$2,310	$2,514
slab houses only	$2,163	$1,867	$1,655	$1,999	$2,165	$2,639
vented crawlspace houses only		$1,890	$1,711			
2021 with HVAC option	$2,045	$1,768	$1,680	$1,959	$2,113	$2,266
2021 with Water Heater option	$2,028	$1,741	$1,761	$2,106	$2,283	$2,505
2021 with Ventilation option	$2,144	$1,876	$1,778	$2,104	$2,251	$2,495
2021 with Duct option, slab house	$2,046	$1,789	$1,585	$1,889	$1,985	$2,418
2021 with Duct option, vented crawlspace		$1,845	$1,644			

Table 20. Energy Cost Savings of Additional Efficiency Package Options relative to 2021 without packages

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	5.4%	6.4%	6.5%	8.3%	8.5%	9.9%
Water Heater option	6.2%	7.9%	2.0%	1.5%	1.2%	0.3%
Ventilation option	0.9%	0.7%	1.1%	1.5%	2.6%	0.8%
Duct option, slab house	5.4%	4.2%	4.2%	5.5%	8.3%	8.4%
Duct option, vented crawlspace house		2.4%	3.9%			

Table 21. Simple payback of efficiency package options relative to 2021 house without packages, years

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	49	47	11	8	8	6
Water Heater option	10	9	21	24	27	89
Ventilation option	240	226	167	97	54	0
Duct option, slab house	35	53	25	16	10	8
Duct option, vented crawlspace house		0	0			

CONCLUSIONS

Home Innovation conducted a cost effectiveness analysis of the 2021 IECC code changes for residential construction based on incremental construction costs and energy use costs developed for a Standard Reference House with multiple configurations and in multiple locations.

Key findings are summarized here for the 2021 Reference House relative to the 2018 Baseline Reference House, based on weighted averages within climate zones (foundation type, wall type) and across climates for national averages (based on housing starts):

- The national average incremental construction cost ranges from $6,548 to $9,301 depending on the additional efficiency package option selected for compliance.
- Depending on climate zone, the weighted average incremental construction cost may range up to $11,900.
- The national average energy use cost savings ranges from 6.4% to 11.6% depending on the additional efficiency package option selected for compliance.
- The national average simple payback for complying with the 2021 IECC ranges from 32 years to 67 years.
- The average simple paybacks for selected individual envelope code changes within associated climate zones are 78-103 years for wall continuous insulation, 23-28 years for slab insulation, and 90-177 years for ceiling insulation.
- The average simple payback for the additional efficiency package options within associated climate zones is 6-11 years for natural gas heating and 47-49 years for heat pump heating, 9-10 years for a heat pump water heater in CZ 2-3 relative to a conventional resistance water heater and 21-27 years for a natural gas water heater (except 89 years for a gas water heater in CZ 7), 54-240 years for Ventilation option, 25-53 years for Duct option for slab houses in CZ 2-4 and 8-16 years for Duct option in CZ 5-8.

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

The estimated construction costs for the selected individual code changes are shown below. Construction costs were developed using RSMeans[8] 2021 Residential Data. Costs for mechanical equipment were sourced from distributor web sites[9]. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of rater web sites. See Appendix B for costs by climate zone.

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of the Code Change:

This code change revised the definition of HIGH EFFICACY LIGHT SOURCES. The new minimum efficacy is 65 lumens per watt for lamps and 45 lumens per watt for luminaires. Previously, the minimum efficacy was 60 lumens per watt for lamps over 40 watts, 50 for lamps over 15 watts to 40 watts, and 40 for lamps 15 watts or less (R202). The code change excludes kitchen appliance lighting fixtures from high efficacy requirements for permanently installed lighting fixtures. (R404.1).

Cost Implication of the Code Change:

This code change should not increase the cost of construction as typical CFL and LED lamps meet or exceed the new efficacy requirements. (See RE 145 for lighting changes that do impact cost.)

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[8] RSMeans, https://www.rsmeans.com/

[9] Mechanical equipment cost sources include: hvacdirect.com; supplyhouse.com; acwholesalers.com; menards.com

RE18, RE20, RE21

Reference Code Section
R401.3 Certificate

Summary of the Code Change:
This code change requires additional information on the certificate for PV systems (RE18), code edition and compliance path (RE20), and area-weighted average insulation value (RE21).

Cost Implication of the Code Change:
This code change will increase the cost of construction. The analysis is based on an estimate of the additional time required by a rater to collect and add this information to the certificate.

Cost to add information to the certificate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental time for rater	HR				80.00	1	80
Total to Builder							**80**
Total to Consumer							**99**

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of the Code Change:

This code change increases the prescriptive R-value of continuous insulation (c.i.) on frame walls in CZ 4-5 from "R20 or 13+5" to "R20+5 or 13+10 or 0+15".

Cost Implication of the Code Change:

This code change will increase the cost of construction for frame walls in CZ 4-5. The analysis is based on the cost to increase c.i. from R5 to R10 for 2x4 walls and from none to R5 for 2x6 walls. The costs include associated additional trim at windows and doors and longer fasteners for cladding based on vinyl siding. A weighted average cost is then determined based on market data for walls (per the 2019 ABPS), as shown below.

Weighted Average Cost to Increase Continuous Insulation (c.i.)

Component	Unit	Cost, from below	Weight	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	1,101	24.9%	274
2x6 wall, increase c.i. from R0 to R5	$/house	6,504	72.2%	4,696
Total to Consumer				**4,970**

Cost to increase c.i. from R5 to R10 for 2x4 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(2,675)	(3,986)
XPS, 15 psi, 2", R10	SF	0.83	0.49	1.32	1.72	2,675	4,601
Window/door casing, PVC trim exterior	LF	0.55		0.55	0.61	415	251
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	(21)	(71)
Siding attachment, 3.5" common nail galv	LB	1.78		1.78	1.96	49	96
Total to Builder							**892**
Total to Consumer							**1,101**

Cost to increase c.i. from none to R5 for 2x6 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	2,675	3,986
Door/window casing, PVC trim exterior	LF	0.55	1.47	2.02	3.03	415	1,258
Siding attachment, 1.5" roofing nail galv	LB	2.78		2.78	3.06	(13.0)	(40)
Siding attachment, 2.5" roofing nail galv	LB	2.78		2.78	3.06	21.0	64
Total to Builder							**5,268**
Total to Consumer							**6,504**

RE32

Reference Code Section
Table R402.1.2, Table R402.1.3

Summary of the Code Change:
This code change increases the slab edge insulation requirements in CZ 3 from none to R10/2 (R10, 2-feet deep) and in CZ 4-5 from 10/2 to 10/4 (R10, 4-feet deep).

Cost Implication of the Code Change:
This code change will increase the cost of construction for slab homes in CZ 3-5. The analysis is based on the cost to install this insulation at the Reference House with a foundation perimeter of 200 linear feet, so the quantity of insulation 2-feet deep is 400 square feet. Note that the incremental quantity and cost of insulation is assumed to be the same for CZ 3 and CZ 4-5; however, for CZ 3, the cost of flashing at the top edge of the insulation is included.

Cost of additional slab edge insulation, CZ 3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10	SF	1.23	0.40	1.63	2.01	400	804
Flashing, vinyl coated aluminum	SF	1.92	1.17	3.09	4.03	200	806
Total to Builder							**1,610**
Total to Consumer							**1,988**

Cost of additional slab edge insulation, CZ 4-5

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10	SF	1.23	0.40	1.63	2.01	400	804
Total to Builder							**804**
Total to Consumer							**993**

RE33, RE36

Reference Code Section

Table R402.1.2, Table R402.1.3, R402.2.1

Summary of the Code Change:

These code changes increase ceiling insulation from R38 to R39 in CZ 2-3 (RE33) and from R49 to R60 in CZ 4-8 (RE36). The code change also updates the exception for ceiling insulation above wall top plates at eaves to include where R60 is now required.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 2-8. The analysis is based on the incremental cost of blown fiberglass insulation in a vented attic. The incremental cost is assumed to be the same for both changes. The analysis does not address any potential costs associated with raised-heel trusses.

Cost to Increase ceiling insulation from R-38 to R-49 or from R-49 to R-60

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-38 attic insulation, blown fg	SF	0.69	0.61	0.36	1.66	2.14	(1,875)	(4,013)
R-49 attic insulation, blown fg	SF	0.91	0.76	0.45	2.12	2.73	1,875	5,119
Total to Builder								**1,106**
Total to Consumer								**1,366**

RE34

Reference Code Section
Table R402.1.3

Summary of the Code Change:
This code change removed the footnote "g" exception for reduced insulation in floors for CZ 5 and Marine 4 through CZ 8. The deleted exception alternatively allowed insulation sufficient to fill the framing cavity providing not less than an R-value of R-19, instead of the prescribed values of R30 (CZ 5-6 and Marine 4) or R38 (CZ 7-8). Note that the prescribed floor insulation values did not change for 2021.

Cost Implication of the Code Change:
This code change may increase the cost of construction in some cases (e.g., installing spray foam insulation with a higher R-value per inch, or installing taller floor joists to accommodate sufficient insulation, may now be required to meet prescriptive floor insulation values), but there is no cost impact for the Reference House because the Reference House does not have floors above unconditioned space.

RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

This code change reduces the prescriptive maximum U-factor for windows in CZ 3-4 from 0.32 to 0.30. The change also adds a footnote that a maximum window U-factor of 0.32 shall apply in CZ 5/Marine 4 through CZ 8 for buildings located above 4,000 feet in elevation above sea level or in windborne debris regions where protection of openings is required.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 3-4. The analysis is based on an incremental material cost of $0.15/SF for improving window U-factor from 0.32 to 0.30 as determined by the California Energy Commission[10].

The Department of Energy and EPA Energy Star along with those involved in the development of energy codes have traditionally had problems developing a clear incremental cost for changes in window thermal performance. An earlier report based on cost data collected by the U.S. Department of Energy indicated an incremental cost of $0.18/SF window area for improving U-value from 0.35 to 0.32[11]. In this analysis, prices used to develop the incremental cost associated with the code change are a best guess based on the available data.

Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental cost of window	SF	0.15		0.15	0.17	375	62
Total to Builder							**62**
Total to Consumer							**76**

[10] CEC report, see table 9: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369

[11] https://www.energycodes.gov/sites/default/files/documents/iecc2018_R-2_analysis_final.pdf

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

This code change changes the window SHGC in CZ 5 and CZ 4C Marine from "NR" to "0.40".

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.40 SHGC in "North-Central" climates since 2015. Further, energy modeling typically assigns a value of 0.40 where SHGC is NR.

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of the Code Change:

This code change reduces the average maximum fenestration SHGC permitted using tradeoffs in CZ 0-3 from 0.50 to 0.40.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.25 SHGC in "South-Central" and "Southern" climates since 2015.

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change does not add new requirements; rather, it separates the prescriptive (required insulation levels) and mandatory (weatherstripping) provisions into separate sections.

Cost Implication of the Code Change:

This code change does not directly impact the cost of construction. However, additional insulation is required due to increased prescriptive ceiling insulation requirements. The analysis is based on the cost to install an additional R-11 insulation above a 24" x 36" attic access hatch.

Cost to increase the insulation above an attic access by R-11

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
EPS, 3" thick, R-11.5	SF	0.96	0.40	1.36	1.72	6	10
Total to Builder							**10**
Total to Consumer							**13**

RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change adds an exception to the attic access insulation requirement. Attic pull-down stairs in CZ 0-4 are not required to comply with the insulation level of the surrounding surfaces provided that the hatch meets all the following: average maximum U-0.10 insulation or average minimum R-10 insulation; at least 75% of the panel area shall be minimum R-13 insulation; maximum net area of the framed opening is 13.5 SF; the perimeter of the hatch shall be weatherstripped.

Cost Implication of the Code Change:

This code change may decrease construction costs where pull-down attic stairs are utilized in CZ 0-4. The analysis is based on the cost savings of less insulation above the access: for this study, R13 versus R49 in CZ 2-3, and R13 versus R60 in CZ 4.

Cost savings to reduce insulation above attic pull-down stair for CZ 2-3 (R49 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer)	SF	0.68	0.45	1.13	1.49	13.5	20
XPS, 15 psi, 2", R10 (one 2" layer)	SF	0.83	0.49	1.32	1.72	13.5	23
XPS, 15 psi, 2", R10 (five 2" layers)	SF	0.83	0.49	1.32	1.72	(67.5)	(116)
Total to Builder							(73)
Total to Consumer							(90)

Cost savings to reduce insulation above attic pull-down stair for CZ 4 (R60 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer)	SF	0.68	0.45	1.13	1.49	13.5	20
XPS, 15 psi, 2", R10 (one 2" layer)	SF	0.83	0.49	1.32	1.72	13.5	23
XPS, 15 psi, 2", R10 (six 2" layers)	SF	0.83	0.49	1.32	1.72	(81.0)	(139)
Total to Builder							(96)
Total to Consumer							(119)

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change adds a requirement for baffles to prevent loose-fill attic insulation from spilling into higher to lower sections of the attic, and from attics covering conditioned spaces to unconditioned spaces. Baffles at the attic access to prevent spilling into livings space are still required (although those must be taller now).

Cost Implication of the Code Change:

This code change will increase the cost of construction for the attic access hatch. This code change may increase the cost of construction where ceiling height varies or attics above unconditioned spaces.

The analysis develops an incremental cost to construct a taller baffle (by 4") for a 24" x 36" attic access hatch for all CZs. The analysis also develops a cost to install baffles for a hypothetical tray ceiling (est. 48 LF): for blown fiberglass insulation at R-3.2/inch, the baffles would need to be 16" tall plus a 3" nailing surface for CZ 2-3 and 19" tall plus a 3" nailing surface for CZ 4-7.

Cost to increase the height of insulation baffles at attic access hatch

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 3/4" CDX	SF	1.38	0.60	1.98	2.50	4	10
Total to Builder							**10**
Total to Consumer							**12**

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 2-3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX	SF	1.00	0.52	1.52	1.95	76	148
Total to Builder							**148**
Total to Consumer							**183**

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 4-8

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX	SF	1.00	0.52	1.52	1.95	96	187
Total to Builder							**187**
Total to Consumer							**231**

RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of the Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced, where c.i. is required and structural sheathing covers 40 percent or less of the gross wall area of all exterior walls, to result in a consistent total sheathing thickness on areas of the walls covered by structural sheathing.

Cost Implication of the Code Change:

This code change would increase the cost of construction in CZ 3-8 where the exception was utilized. The analysis is based on the additional cost to increase the foam sheathing thickness to 1-1/2-inch where it was 1-inch before, and to 1-inch where it was ½-inch before over the structural sheathing. A second cost is developed separately based on the additional cost to install ½-inch structural sheathing over the entire wall area and 1-inch thick foam sheathing over the structural sheathing. Both costs are based on using XPS foam sheathing and the assumption that wood structural sheathing originally covered 40% of the wall area (1,070 SF) and the remaining 60% of the wall area (1,605 SF) was originally covered by foam only (i.e., not by wood structural sheathing).

Cost to install additional 1/2-inch thickness of continuous insulation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3	SF	0.60	0.43	1.03	1.37	(1,070)	(1,465)
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	1,070	1,594
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(1,605)	(2,391)
XPS, 15 psi, 1.5", R7.5	SF	0.76	0.49	1.25	1.64	1,605	2,639
Window/door casing, add 1/2"	LF	0.23		0.28	0.31	415	128
Siding attachment, 2" roofing nail galv	LB	3.06		3.06	3.37	(17)	(57)
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	21	71
Total to Builder							**518**
Total to Consumer							**640**

Cost to install OSB over entire wall and cover with 1-inch XPS

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3	SF	0.60	0.43	1.03	1.37	(1,070)	(1,465)
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	1,070	1,594
OSB, wall, 1/2"	SF	0.41	0.44	0.85	1.17	1,605	1,878
Window/door casing, add 1/2"	LF	0.23		0.28	0.31	415	128
Siding attachment, 2" roofing nail galv	LB	3.06		3.06	3.37	(17)	(57)
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	21	71
Total to Builder							**2,148**
Total to Consumer							**2,652**

RE55

Reference Code Section
R402.2.8 Basement walls

Summary of the Code Change:
This code change adds requirements for how to insulate and seal unconditioned basements including at the floor overhead, walls surrounding the stairway, door leading to the basement from conditioned space; the requirements also include no uninsulated duct, domestic hot water or hydronic heating surfaces exposed to the basement, and no HVAC supply or return diffusers serving the basement.

Cost Implication of the Code Change:
This code change will increase the cost of construction where insulation requirements are greater for 2021, i.e., increased continuous insulation (c.i.) for exterior walls in CZ 4-5 for this analysis. The analysis develops a cost to increase c.i. in the walls surrounding the stairway. This analysis assumes that builders were already constructing unconditioned basements as described by the code change.

Cost to increase wall insulation in the stairway

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(200)	(298)
XPS, 15 psi, 2", R10	SF	0.83	0.49	1.32	1.72	200	344
Drywall screw, 2.5"	LB	5.98		5.98	6.58	(1.3)	(9)
Drywall screw, 3.5"	LB	5.98		5.98	6.58	1.6	10
Total to Builder							**48**
Total to Consumer							**59**

RE72

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of the Code Change:

This code change adds a new requirement that "narrow cavities of an inch or less that are not able to be insulated shall be air sealed".

Cost Implication of the Code Change:

This code change may increase the cost of construction as applicable. The analysis is based on an estimated quantity of small cavities that would require the installation of sealant.

Cost to install additional sealant for narrow framing cavities

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 3/4" x 1" bead	LF	1.28	1.28	2.56	3.51	36	126
Total to Builder							**126**
Total to Consumer							**156**

RE82

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of the Code Change:

This code change adds a new requirement to air seal the rim board at the sill plate and subfloor. Rim areas in vented crawl spaces and attics are exempt.

Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis is based on the linear feet of sealant required for the Reference House designs with a foundation perimeter of 200 LF and a second story perimeter of 100 LF. For basement and unvented crawlspace designs, the quantity of sealant is 600 LF (300 LF of rim area, multiplied by two to capture the sealant required at both the sill plate and subfloor). For slab and vented crawlspace designs, the quantity of sealant is 200 LF (100 LF of rim area for the second floor).

Cost to install sealant at rim joists for basement or unvented crawlspace designs

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 1/4" x 1/4" bead	LF	0.10	0.96	1.06	1.69	600	1,014
Total to Builder							**1,014**
Total to Consumer							**1,252**

Cost to install sealant at rim joists for slab or vented crawlspace designs

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 1/4" x 1/4" bead	LF	0.10	0.96	1.06	1.69	200	338
Total to Builder							**338**
Total to Consumer							**417**

RE96

Reference Code Section
R402.4.1.2 Testing

Summary of the Code Change:
This code change makes house air tightness prescriptive and allows a trade-off option up to 5.0 ACH50 or 0.28 CFM/SF enclosure area (0.30 CFM/SF exception for attached dwellings and dwellings 1,500 SF or smaller). The prescriptive limits remain the same: 5.0 ACH50 in CZ 1-2; 3.0 ACH50 in CZ 3-8.

Cost Implication of the Code Change:
This code change may decrease construction costs in some cases where a builder trades-off air leakage for other efficiency improvements for a house in CZ 3-8, but there is assumed to be no cost impact for the Reference House because there is not a straightforward approach to reasonably quantify such a change.

RE103

Reference Code Section

R402.4.6 Electrical and communication outlet boxes (air-sealed boxes)

Summary of the Code Change:

This code change adds a new section that requires electrical and communication outlet boxes installed in the building thermal envelope (i.e., exterior walls and ceilings adjacent to vented attics) to be air sealed. These outlet boxes must be tested and labeled in accordance with NEMA OS 4.

Cost Implication of the Code Change:

This code change will increase the cost of construction for all locations. The analysis is based on the cost to substitute a rated airtight box for a standard blue plastic new-work electrical box, using an estimated quantity of affected boxes for the Reference House.

Cost of air sealed electrical and communication outlet boxes

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
Standard electric box, 1-gang	EA	0.34		0.34	0.37	(42)	(16)
NEMA OS 4 Airtight box, 1-gang	EA	5.52		5.52	6.07	42	255
Standard electric box, ceiling	EA	1.19		1.19	1.31	(10)	(13)
NEMA OS 4 Airtight box, ceiling	EA	6.60		6.60	7.26	10	73
Total to Builder							**299**
Total to Consumer							**369**

***Estimated quantity of affected boxes**

Box type	Quantity
Wall receptacle outlet (one every 10 LF of exterior wall)	30
Wall switch outlet	6
Wall communication outlet	6
Ceiling light fixture/smoke detector	10

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of the Code Change:

This code change modifies the required capabilities for programmable thermostats: in addition to being capable of controlling different set point temperatures at different times of the day, thermostats must now be capable of controlling this for different days of the week (i.e., a 7-day thermostat, versus a 5-2 day or 5-1-1 day).

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases, depending on the make and model of thermostat normally used, but a review of distributor websites indicated the lowest cost programmable thermostat by a leading national manufacturer already has 7-day capability for single-stage heat pump or gas furnace with air conditioner systems. Therefore, this code change is not anticipated to affect the cost of construction. There is not an energy use cost savings associated with this change because the energy modeling does utilize thermostat set-back settings.

RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of the Code Change:

This code change adds requirements for ducts within floor or wall cavities to be considered ducts in conditioned space. The requirements include minimum R-19 insulation for floors above unconditioned space, e.g., above a garage, so there are implications for CZ 1-2 where the prescriptive minimum floor insulation is R-13.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases although the Reference House does not have floors above unconditioned space and it is assumed there are no ducts within any wall cavities. The analysis is based on the incremental cost to install R-19 floor insulation instead of R-13 above a garage, assuming ducts occupy two joist bays (each 2' wide x 20' long), and to substitute oval duct for round duct so that the oval duct (typically 3") plus the R-19 insulation (typically 5.5") fits within the height of a 2x10 floor joist.

Cost to increase floor insulation within joist bay from R-13 to R-19

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
R-13 unfaced fiberglass batt	SF	0.49	0.42	0.91	1.22	(80)	(98)
R-19 unfaced fiberglass batt	SF	0.60	0.49	1.09	1.46	80	117
7" round metal duct	LF	2.00		2.00	2.20	(40)	(88)
7" oval metal duct	LF	3.16		3.16	3.48	40	139
Total to Builder							**70**
Total to Consumer							**87**

RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of the Code Change:

This code change removes the exception for testing where ducts and air handlers are located entirely within the building thermal envelope (R403.3.5). The code change also increases the total leakage limit from 4.0 to 8.0 CFM25/100SFcfa where ducts and air handlers are located entirely within the building thermal envelope (R403.3.6).

Cost Implication of the Code Change:

This code change will increase the cost of construction where ducts and air handlers are already installed in conditioned space but testing for duct leakage is now required. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Any cost of remediation for a failed test is not included. For the Reference Houses, it is assumed that this test will now be required for basement and unvented crawlspace designs.

Estimated cost of the duct leakage test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	EA				200.00	1	200
Total to Builder							**200**
Total to Consumer							**247**

RE130

Reference Code Section
R403.6.3 Testing (new)

Summary of the Code Change:
This code change requires whole-dwelling mechanical ventilation systems to be tested and verified to provide the minimum required ventilation flow rates.

Cost Implication of the Code Change:
This code change will increase the cost of construction for all houses. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Testing is in addition to duct leakage testing. Testing is now required for the ventilation system of record (e.g., bath exhaust fan, HRV/ERV, supply-type ducted to the return plenum of a central system). Any cost of remediation for a failed test is not included.

Estimated cost of the mechanical ventilation test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	EA				50.00	1	50
Total to Builder							**50**
Total to Consumer							**62**

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

This code change updates the fan efficacy requirements for fans used to provide whole-dwelling mechanical ventilation (supply and exhaust fans now must meet the current EnergyStar requirements). The minimum efficacy for an exhaust fan increased from 1.4 to 2.8 CFM/watt for airflow rates less than 90 CFM and from 2.8 to 3.5 CFM/watt for airflow rates 90 CFM and above. The minimum efficacy for an ERV/HRV did not change.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases depending on the make and model of fan already being installed. The Reference House uses a bath exhaust fan for whole-dwelling mechanical ventilation and requires a continuous ventilation rate of 63 CFM for slab and crawlspace designs or 82 CFM for basement designs. The analysis is based on the case where an exhaust fan with an efficacy of at least 1.4 CFM/watt but less than 2.8 CFM/watt must be replaced with unit with efficacy of at least 2.8 CFM/watt.

Incremental cost of high efficacy bath exhaust fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, 1.8 CFM/W (Air King)	EA	40.15		40.15	44.17	(1)	(44)
Bath fan, 90 CFM, EnergyStar (Air King)	EA	88.43		88.43	97.27	1	97
Total to Builder							**53**
Total to Consumer							**66**

RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

This code change adds efficacy requirements to air-handlers where integrated with whole-dwelling mechanical ventilation: minimum 1.2 cfm/watt, the "design outdoor airflow rate/watts of fan used".

Cost Implication of the Code Change:

This code change may increase the cost of construction for integrated supply-type ventilation (ducted to the return plenum of the HVAC system) or balanced ventilation that is partially ducted (HRV or ERV ducting integrated with the HVAC system).

This change does not impact the Reference House that utilizes exhaust ventilation. However, a cost is developed for supply-type ventilation (this cost will also be a component of installing balanced ventilation where an HRV or ERV is integrated with the central duct system). The analysis is based on substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement. During fan-only operation (no heating or cooling), the variable-speed furnace or air handler can be adjusted to operate at 25% of normal heating or cooling airflow, and at this lower airflow system will generally meet the efficacy requirement (although this value is typically not published in the manufacturer product data). Additionally, at this lower airflow, the differential pressure at the return plenum will not be sufficient to draw in the required amount of outdoor air, so an additional ventilation fan will normally be required. The analysis assumes the existing ventilation control is already accounted for.

Incremental cost of variable-speed furnace

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 AFUE, multi-speed	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed	EA	1323.00		1323.00	1455.30	1	1,455
Total to Builder							**556**
Total to Consumer							**686**

Cost of both variable-speed furnace and ventilator fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Furnace, total to Builder from above							556
Ventilator fan with damper	EA	293.04	39.90	332.94	388.18	1	388
Ventilation damper	EA	85.99		85.99	94.59	(1)	(95)
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Total to Builder							**989**
Total to Consumer							**1,222**

RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of the Code Change:

This code change requires an HRV or ERV system in CZ 7-8. The system shall be balanced with a minimum 65% SRE at 32°F at a flow greater than or equal to design airflow.

Note that in the 2021 IRC, Section M1505.4.3, there is a whole-dwelling ventilation rate credit of 30% available for a balanced ventilation system with a ducted supply to each bedroom and to one or more of the following rooms: living room; dining room; kitchen.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 7-8. The analysis develops a cost to install an ERV that meets the efficiency requirements and substitutes a standard bath fan for a high efficacy fan that was used for exhaust-type whole-dwelling ventilation. The cost also includes substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement for air handlers integrated with whole-dwelling mechanical ventilation (RE134); alternatively, the ERV would need to be ducted independently.

Cost to install an ERV

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Gas furnace, 80 AFUE, multi-speed blower	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed blower	EA	1323.00		1323.00	1455.30	1	1,455
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,597**
Total to Consumer							**3,206**

RE145

Reference Code Section

R404.1 Lighting equipment; R404.2 Interior lighting controls (new)

Summary of the Code Change:

This code change mandates that all permanently installed lighting fixtures contain only high-efficacy lamps (previously 90%) and have built-in lighting controls (dimmer, occupant sensor, or other control) excluding bathrooms, hallways, exterior lighting fixtures, lighting designed for safety or security.

Cost Implication of the Code Change:

This code change will increase the cost of construction for all houses. The analysis is based on an estimated quantity of high-efficacy lamps and dimmers required at the Reference Houses.

Cost of high-efficacy lamps and dimmer switches (slab)

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
CFL lamp	EA	1.99		1.99	2.19	4	9
Incandescent lamp	EA	1.02		1.04	1.12	(4)	(4)
Dimmer switch, toggle	EA	9.99		9.99	10.99	4	44
Standard toggle switch	EA	1.99		1.99	2.19	(4)	(9)
Total to Builder							**39**
Total to Consumer							**49**

Cost of high-efficacy lamps and dimmer switches (basement or crawl space)

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
CFL lamp	EA	1.99		1.99	2.19	4	9
Incandescent lamp	EA	1.02		1.99	1.12	(4)	(4)
Dimmer switch, toggle	EA	9.99		9.99	10.99	5	55
Standard toggle switch	EA	1.99		1.99	2.19	(5)	(11)
Total to Builder							**48**
Total to Consumer							**60**

*Quantities		
Room	**Lamps**	**Dimmer**
Dining room	6	1
Kitchen	6	1
Breakfast	4	1
Family Room	2	1
Halls	2	0
Baths (3)	10	0
Bedrooms	0	0
Exterior	2	0
Basement or crawlspace	4	1
Total, basement or crawl	36	5
Total, slab	32	4
Additional lamps required	4	

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of the Code Change:

This code change requires compliance with Section C405.4 of the IECC for connected exterior lighting for Group R-2, R-3, and R-4 buildings.

Cost Implication of the Code Change:

This code change will not impact the cost of construction for homes constructed to the IRC.

RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of the Code Change:

This code change requires automatic controls where permanently installed exterior lighting power exceeds 30 watts.

Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis assumes two 100-watt equivalent, 18-watt actual, exterior lamps and is based on installing two light-sensing devices.

Cost of exterior lighting control with light sensor

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
Control, 100-watt rated, screw-in type	EA	9.20		9.20	10.12	2	20
Total to Builder							**20**
Total to Consumer							**25**

RE151

Reference Code Section
R405.2

Summary of the Code Change:
This code change creates a backstop for the performance path that requires the building thermal envelope greater than or equal to levels of efficiency and solar heat gain coefficients in the 2009 IECC.

Cost Implication of the Code Change:
It is anticipated that this change will not affect the cost of construction.

RE178

Reference Code Section

Table R405.4.2

Summary of the Code Change:

This code change updates the mechanical ventilation system type for the standard reference design to match the proposed design when using the performance compliance option.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction.

RE209

Reference Code Section

R401.2.5 Additional energy efficiency (new); R408 Additional efficiency package options (new)

Summary of the Code Change:

This code change establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency. Compliance for the prescriptive approach requires installing at least one of the five prescribed efficiency package options:

- Enhanced envelope performance (5% UA and SHGC improvement)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER airs source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). [For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met, and houses in CZ 2 were modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50)].

Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis evaluates the costs associated with the additional efficiency package options except for the enhanced envelope option.

HVAC equipment option for Gas House with baseline 13 SEER AC (CZ 5-7 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80kBtuh, AFUE 80%	EA	761.00		761.00	837.10	(1)	(837)
Gas Chimney Vent, 4" dia.	LF	9.65	8.45	18.10	24.50	(25)	(613)
Gas Chimney Vent, 3" dia. (water heater)	LF	7.95	8.00	15.95	22.00	25	550
Gas furnace, 80kBtuh, AFUE 95%	EA	1,295.00		1,295.00	1,424.50	1	1,425
Vent piping, PVC, 2" dia.	LF	3.05	3.02	6.07	8.30	40	332
2" concentric vent kit	EA	59.95		59.95	65.95	1	66
Condenser, 3 ton, 13 SEER	EA	1,085.00		1,085.00	1,193.50	(1)	(1,194)
Condenser, 3 ton, 16 SEER	EA	1,346.00		1,346.00	1,480.60	1	1,481
Total to Builder							**1,210**
Total to Consumer							**1,494**

HVAC equipment option for Gas House adjusted for baseline 14 SEER AC (CZ 2-4 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Total to Builder, from above							**1,210**
Condenser, 3-ton, 14 SEER	EA	1,215.00		1,215.00	1,336.50	(1)	(1,337)
Condenser, 3-ton, 13 SEER	EA	1,085.00		1,085.00	1,193.50	1	1,194
Total to Builder							**1,067**
Total to Consumer							**1,317**

HVAC option for Electric House: variable speed inverter heat pump, rated to 7F (CZ 2-4)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER	EA	1,629.00		1,629.00	1,791.90	(1)	(1,792)
Air Handler, matching	EA	988.00		988.00	1,086.80	(1)	(1,087)
Heat Pump, inverter, minimum 10 HSPF/16 SEER, 7F rated	EA	6,830.00		6,830.00	7,513.00	1	7,513
Total to Builder							**4,634**
Total to Consumer							**5,721**

HVAC option for Electric House: variable speed inverter heat pump, rated to -13F (CZ 5-7)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER	EA	1,629.00		1,629.00	1,791.90	(1)	(1,792)
Air Handler, matching	EA	988.00		988.00	1,086.80	(1)	(1,087)
Heat Pump, inverter, minimum 10 HSPF/16 SEER, -13F rated	EA	8,652.00		8,652.00	9,517.20	1	9,517
Total to Builder							**6,639**
Total to Consumer							**8,196**

Water Heater option for Gas House: Tankless Direct Vent Water Heater

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
40 gal gas water heater, 0.58 UEF	EA	559.00	165.00	724.00	883.52	(1)	(884)
Tankless gas water heater, 0.82 UEF	EA	799.00	174.00	973.00	1,162.17	1	1,162
Concentric vent wall termination kit	EA	90.00		90.00	99.00	1	99
Concentric vent 39" extension	EA	37.59		37.59	41.35	1	41
Gas Chimney Vent, 3" dia. (WH connector)	LF	7.95	8.00	15.95	22.00	(4)	(88)
Gas piping, 1/2"	LF	2.69	5.25	7.94	11.50	(10)	(115)
Gas piping, 1"	LF	3.73	6.25	9.98	14.25	10	143
15-amp circuit, toggle, 40' #14/2 NM	EA	51.00	85.50	136.50	195.00	1	195
GFCI 15-amp, 1-pole breaker	EA	41.99		41.99	46.19	1	46
Total to Builder							**600**
Total to Consumer							**740**

Water Heater option for Electric House: 50 gal Heat Pump Water Heater (HPWH)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
50 gal electric water heater	EA	419.00		419.00	460.90	(1)	(461)
HPWH, 50 gal, minimum 2.0 EF	EA	1,199.00		1,199.00	1,318.90	1	1,319
Mixing valve	EA	175.00	16.50	191.50	220	1	220
Total to Builder							**1,078**
Total to Consumer							**1,331**

Ventilation Option Gas House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Gas furnace, 80 AFUE, multi-speed blower	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed blower	EA	1323.00		1323.00	1455.30	1	1,455
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,597**
Total to Consumer							**3,206**

Ventilation Option Electric House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Heat Pump system, multi-speed blower	EA	2394.00		2394.00	2633.40	(1)	(2,633)
Heat Pump system, variable-speed	EA	2828.00		2828.00	3110.80	1	3,111
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,518**
Total to Consumer							**3,109**

Ventilation Option Electric House in CZ 2

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Associated ERV cost to builder from above							2,518
Improve ACH50 from 5 to 3, estimate							1,200
Total to Builder							**3,718**
Total to Consumer							**4,591**

Duct Option: Slab House, Buried Ducts, CZ 2-3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R13 duct: add FSK min R5 over R8 duct	SF	0.27	1.70		1.97	3.14	680	2,135
Add ceiling insulation, R49 f.g. blown	SF	0.91	0.76	0.45	2.12	2.73	340	928
Mechanical closet, 3'x4', partition wall	LF	7.40	4.89		12.29	16.15	10	162
Mechanical closet, drywall, finished	SF	0.38	0.61		0.99	1.41	140	197
Mechanical closet door	EA	135.00	34.50		169.50	205.00	1	205
Delete attic platform decking, 3/4, 8'x8'	SF	1.38	0.38		1.76	2.14	(64)	(137)
Delete attic platform joist framing, 2x12	LF	2.53	0.58		3.11	3.73	(40)	(149)
Total to Builder								**3,341**
Total to Consumer								**4,125**

Duct Option: Slab House, Buried Ducts, CZ 4-7

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Add ceiling insulation, R60 f.g. blown	SF	1.13	0.91	0.54	2.58	3.32	340	1,128
Mechanical closet, 3'x4', partition wall	LF	7.40	4.89		12.29	16.15	10	162
Mechanical closet, drywall, finished	SF	0.38	0.61		0.99	1.41	140	197
Mechanical closet door	EA	135.00	34.50		169.50	205.00	1	205
Delete attic platform decking, 3/4, 8'x8'	SF	1.38	0.38		1.76	2.14	(64)	(137)
Delete attic platform joist framing, 2x12	LF	2.53	0.58		3.11	3.73	(40)	(149)
Total to Builder								**1,406**
Total to Consumer								**1,736**

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19	SF	0.60	0.49		1.09	1.46	(1,875)	(2,738)
Wall insulation, foil-faced polyiso, 1", R6	SF	0.81	0.37		1.18	1.50	1000	1,502
Foundation vents	EA	7.98			7.98	8.78	(6)	(53)
Class 1 vapor retarder on ground	SF	0.08	0.08		0.16	0.22	1875	413
Supply duct, 38 cfm (1 cfm/50sf)	EA				125.00	137.50	1	138
Transfer grille	EA	24.00	13.30		37.30	48.50	1	49
Total to Builder								(690)
Total to Consumer								(852)

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 4

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19	SF	0.60	0.49		1.09	1.46	(1,875)	(2,738)
Wall insulation, foil-faced polyiso, 2", R12	SF	1.25	0.40		1.65	2.04	1000	2,035
Foundation vents	EA	7.98			7.98	8.78	(6)	(53)
Class 1 vapor retarder on ground	SF	0.08	0.08		0.16	0.22	1875	413
Supply duct, 38 cfm (1 cfm/50sf)	EA				125.00	137.50	1	138
Transfer grille	EA	24.00	13.30		37.30	48.50	1	49
Total to Builder								(157)
Total to Consumer								(193)

CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of the Code Change:

This code change adds a new requirement for an insulation certificate to certify the installed R-value of insulation products without an observable manufacturer's R-value mark such as blown-in attic insulation. The certificate must be left by the installer immediately after installation in a conspicuous location within the building.

Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis is based on the estimated additional time for the installer to complete and post the certificate.

Cost to provide insulation certificate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Insulation installer	HR		29.23	29.23	48.23	0.25	12
Total to Builder							**12**
Total to Consumer							**15**

CE151.2

Reference Code Section

R202 Defined terms (new); R403.3.1 Ducts located outside conditioned space

Summary of the Code Change:

This code change adds a definition for Thermal Distribution Efficiency (TDE) and requirements for ducts buried underneath buildings.

Cost Implication of the Code Change:

This code change may decrease the cost of construction in some cases, e.g., where ducts are buried beneath buildings, but this change does not impact cost for the Reference House.

APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

Incremental Construction Cost of Individual Code Chage for the Reference House

Proposal	Description	Affected CZ	Reference House	CZ 2 Phoenix Mass (30%) Electric Slab 100%	CZ 2 Phoenix Frame (70%) Electric Slab 100%
RE7	Lighting: revised definition of high-efficacy	All	$0		
RE18/20/21	Certificate: additional info	All	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970		
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988		
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366	$1,366	$1,366
RE36	Ceiling insulation R49 to R60	4-7	$1,366		
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA		
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76		
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0		
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0		
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		
"	Air seal rim (slab, vented crawlspace)	All	$417	$417	$417
RE96	House tightness, allows trade-off for performance path	All	$0		
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0		
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206		
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49	$49
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		
RE148	Lighting, commercial	All	NA		
RE149	Lighting: exterior controls	All	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA		
RE178	Performance path ventilation type to match proposed	All	NA		
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA		
	Sub-total without additional efficiency package options			$2,648	$2,648
	Weighted average, foundations				$2,648

Proposal	Description	Nat Ave	CZ 2
	Weighted average without additional efficiency package options	5,477	2,648
RE209	HVAC option	3,824	5,721
RE209	Water Heater option	1,071	1,331
RE209	Ventilation option	3,570	4,591
RE209	Duct option, slab houses	3,074	4,125
RE209	Duct option, vented crawlspace houses	na	
	Total with HVAC option	9,301	8,369
	Total with Water Heater option	6,548	3,979
	Total with Ventilation option	9,047	7,238
	Total with Duct option, slab houses	8,550	6,773
	Total with Duct option, vented crawlspace houses	na	

Incremental Construction Cost of Individual Code Chage for the Reference House

Proposal	Description	Affected CZ	Reference House	CZ 3 Memphis Mass Wall (10%) Electric Slab 75%	Basement 10%	Crawl 15%	Frame Wall (90%) Electric Slab 75%	Basement 10%	Crawl 15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988	$1,988			$1,988		
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993						
RE33	Ceiling insulation R38 to R49	2-3	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE36	Ceiling insulation R49 to R60	4-7	$1,366						
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76	$76	$76	$76	$76	$76	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252			$1,252	
"	Air seal rim (slab, vented crawlspace)	All	$417	$417		$417	$417		$417
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247			$247	
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$4,712	$3,816	$2,735	$4,712	$3,816	$2,735
	Weighted average, foundations					$4,326			$4,326
			Nat Ave			**CZ 3**			
	Weighted average without additional efficiency package options		5,477			4,326			
RE209	HVAC option		3,824			5,721			
RE209	Water Heater option		1,071			1,331			
RE209	Ventilation option		3,570			3,109			
RE209	Duct option, slab houses		3,074			4,125			
RE209	Duct option, vented crawlspace houses		na			(852)			
	Total with HVAC option		9,301			10,047			
	Total with Water Heater option		6,548			5,657			
	Total with Ventilation option		9,047			7,435			
	Total with Duct option, slab houses		8,550			8,451			
	Total with Duct option, vented crawlspace houses		na			3,474			

Incremental Construction Cost of Individual Code Chage for the Reference House

Proposal	Description	Affected CZ	Reference House	Slab 20%	CZ 4 Baltimore Frame Wall Gas Basement 60%	Crawl 20%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970	$4,970	$4,970	$4,970
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988			
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993	$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366			
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76	$76	$76	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	
"	Air seal rim (slab, vented crawlspace)	All	$417	$417		$417
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package options			$8,686	$8,786	$7,705
	Weighted average, foundations					$8,550
			Nat Ave		**CZ 4**	
	Weighted average without additional efficiency package options		5,477		8,550	
RE209	HVAC option		3,824		1,317	
RE209	Water Heater option		1,071		740	
RE209	Ventilation option		3,570		3,206	
RE209	Duct option, slab houses		3,074		1,736	
RE209	Duct option, vented crawlspace houses		na		(193)	
	Total with HVAC option		9,301		9,867	
	Total with Water Heater option		6,548		9,290	
	Total with Ventilation option		9,047		11,755	
	Total with Duct option, slab houses		8,550		10,286	
	Total with Duct option, vented crawlspace houses		na		8,356	

Incremental Construction Cost of Individual Code Chage for the Reference House

				CZ 5 Chicago					
					Frame Wall Gas (60%)			Frame Wall Electric (40%)	
Proposal	Description	Affected CZ	Reference House	Slab 15%	Basement 70%	Crawl 15%	Slab 15%	Basement 70%	Crawl 15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970	$4,970	$4,970	$4,970	$4,970	$4,970	$4,970
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988						
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993	$993			$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366						
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76						
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	$1,252		$1,252	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417	$417			$417		
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	$247		$247	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$8,610	$8,710	$8,710	$8,610	$8,710	$8,710
	Weighted average, foundations					$8,695			$8,695
			Nat Ave		CZ 5 Gas			CZ 5 Electric	
	Weighted average without additional efficiency package options		5,477		8,695			8,695	
RE209	HVAC option		3,824		1,494			8,196	
RE209	Water Heater option		1,071		740			2,503	
RE209	Ventilation option		3,570		3,206			3,109	
RE209	Duct option, slab houses		3,074		1,736			1,736	
RE209	Duct option, vented crawlspace houses		na						
	Total with HVAC option		9,301		10,188			16,890	
	Total with Water Heater option		6,548		9,435			11,198	
	Total with Ventilation option		9,047		11,900			11,804	
	Total with Duct option, slab houses		8,550		10,431			10,431	
	Total with Duct option, vented crawlspace houses		na						

Incremental Construction Cost of Individual Code Chage for the Reference House

Proposal	Description	Affected CZ	Reference House	CZ 6 Helena Frame Wall Gas Slab 5%	CZ 6 Helena Frame Wall Gas Basement 90%	CZ 6 Helena Frame Wall Gas Crawl 5%	CZ 7 Duluth Frame Wall Gas Slab 30%	CZ 7 Duluth Frame Wall Gas Basement 5%	CZ 7 Duluth Frame Wall Gas Crawl 65%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988						
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993						
RE33	Ceiling insulation R38 to R49	2-3	$1,366						
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76						
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	$1,252		$1,252	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417	$417			$417		
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	$247		$247	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206				$3,206	$3,206	$3,206
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$2,648	$3,740	$3,740	$5,853	$6,946	$6,946
	Weighted average, foundations					$3,685			$6,618
			Nat Ave		**CZ 6**			**CZ 7**	
	Weighted average without additional efficiency package options		5,477		3,685			6,618	
RE209	HVAC option		3,824		1,494			1,494	
RE209	Water Heater option		1,071		740			740	
RE209	Ventilation option		3,570		3,206			0	
RE209	Duct option, slab houses		3,074		1,736			1,736	
RE209	Duct option, vented crawlspace houses		na						
	Total with HVAC option		9,301		5,179			8,112	
	Total with Water Heater option		6,548		4,426			7,358	
	Total with Ventilation option		9,047		6,891			6,618	
	Total with Duct option, slab houses		8,550		5,421			8,354	
	Total with Duct option, vented crawlspace houses		na						

APPENDIX C: LOCATION ADJUSTMENT FACTORS

State	City	Cost Adjustment Factor	State	City	Cost Adjustment Factor
Alabama	Birmingham	0.84	Montana	Billings	0.89
Alabama	Mobile	0.83	Nebraska	Omaha	0.90
Alaska	Fairbanks	1.21	Nevada	Las Vegas	1.03
Arizona	Phoenix	0.84	New Hampshire	Portsmouth	0.95
Arizona	Tucson	0.84	New Jersey	Jersey City	1.18
Arkansas	Little Rock	0.83	New Mexico	Albuquerque	0.86
California	Alhambra	1.15	New York	Long Island City	1.36
California	Los Angeles	1.15	New York	Syracuse	0.99
California	Riverside	1.13	North Carolina	Charlotte	0.99
California	Stockton	1.20	North Carolina	Hickory	0.93
Colorado	Boulder	0.90	North Carolina	Raleigh	0.94
Colorado	Colorado Springs	0.87	North Dakota	Fargo	0.87
Colorado	Denver	0.91	Ohio	Columbus	0.91
Connecticut	New Haven	1.10	Oklahoma	Oklahoma City	0.84
Delaware	Dover	1.02	Oklahoma	Tulsa	0.83
District of Columbia	Washington, D.C.	0.92	Oregon	Bend	1.02
Florida	Fort Meyers	0.79	Pennsylvania	Norristown	1.05
Florida	Miami	0.83	Pennsylvania	State College	0.94
Florida	Orlando	0.82	Rhode Island	Providence	1.09
Florida	Tampa	0.81	South Carolina	Greenville	0.97
Georgia	Atlanta	0.90	South Dakota	Sioux Falls	0.92
Hawaii	Honolulu	1.22	Tennessee	Memphis	0.87
Idaho	Boise	0.89	Texas	Austin	0.80
Illinois	Chicago	1.25	Texas	Dallas	0.84
Indiana	Indianapolis	0.92	Texas	Houston	0.84
Iowa	Des Moines	0.92	Texas	San Antonio	0.83
Kansas	Wichita	0.81	Utah	Ogden	0.84
Kentucky	Louisville	0.89	Utah	Provo	0.85
Louisiana	Baton Rouge	0.85	Utah	Salt Lake City	0.85
Maine	Portland	0.94	Vermont	Burlington	0.95
Maryland	Baltimore	0.93	Virginia	Fairfax	1.00
Massachusetts	Boston	1.18	Virginia	Winchester	0.99
Michigan	Ann Arbor	0.99	Washington	Tacoma	1.05
Minnesota	Minneapolis	1.09	West Virginia	Charleston	0.94
Mississippi	Biloxi	0.83	Wisconsin	La Crosse	0.95
Missouri	Springfield	0.86	Wyoming	Casper	0.85

*Source: RSMeans *Residential Cost Data 2021*. Sample cities are listed in this table; check RSMeans for additional locations.

APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation and fenestration requirements for the 2018 IECC and 2021 IECC. For comparison purposes, the 2021 IECC values are shown only where those have been changed from the 2018 values.

Insulation and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC.

	CZ 2		CZ 3		CZ 4 except 4C		CZ 5 and 4C		CZ 6		CZ 7	
	Phoenix		Memphis		Baltimore		Chicago		Helena		Duluth	
Component	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**
Fenestration U-factor	0.40		0.32	0.30	0.32	0.30	0.30		0.30		0.30	
Fenestration SHGC	0.25		0.25		0.4		NR	0.40	NR		NR	
Skylight U-factor	0.65		0.55		0.55		0.55		0.55		0.55	
Ceiling R-value	38	49	38	49	49	60	49	60	49	60	49	60
Frame Wall R-value (selected for modeling)	13		13+5		13+5	13+10	13+5	13+10	13+10		13+10	
Mass Wall R-value (<half/>half on interior	4/6		8/13		8/13		13/17		15/20		19/21	
Floor R-value	13		19		19		30		30		38	
Basement wall R-value, ci/cavity	0		5/13		10/13		15/19		15/19		15/19	
Slab R-value/depth	0		0	10/2	10/2	10/4	10/2	10/4	10/4		10/4	
Crawl wall R-value, ci/cavity	0		5/13		10/13		15/19		15/19		15/19	

APPENDIX E: ENERGY USE BY CLIMATE ZONE

		Annual Energy Use CZ 2 Phoenix					
		Mass Wall (30%)			Frame Wall (70%)		
		Electric			Electric		
Configuration		kWh/yr	$/yr	Savings*	kWh/yr	$/yr	Savings*
2018 Baseline	Slab	17,107	2,225		17,087	2,223	
	Basement						
	Crawl**						
2018 + 2021 ceiling insulation	Slab	17,052	2,218	0.3%	17,028	2,215	0.4%
	Basement						
	Crawl**						
2018 + 2021 slab insulation	Slab						
	Ave for CZ						
2018 + 2021 wall cont. insulation	Slab						
	Basement						
	Crawl**						
2018 + 2021 window U-Factor	Slab						
	Basement						
	Crawl**						
2021 without efficiency options	Slab	16,638	2,164	2.7%	16,615	2,162	2.7%
	Basement						
	Crawl**						
2021 + HVAC option	Slab	15,727	2,046	8.0%	15,715	2,045	8.0%
	Basement						
	Crawl**						
2021 + Water Heater option	Slab	15,618	2,030	8.8%	15,589	2,027	8.8%
	Basement						
	Crawl**						
2021 + Ventilation option	Slab	16,506	2,147	3.5%	16,465	2,142	3.6%
	Basement						
	Crawl**						
2021 + Duct option	Slab	15,768	2,051	7.8%	15,715	2,044	8.1%
	Crawl**						

*Cost savings ($/yr) relative to 2018 baseline

**Crawl: vented CZ 3-4; conditioned CZ 5-7

		Annual Energy Use					
		CZ 3 Memphis					
		Mass Wall (10%)			Frame Wall (90%)		
			Electric			Electric	
Configuration		kWh/yr	$/yr	Savings*	kWh/yr	$/yr	Savings*
2018 Baseline	Slab	15618	2031		15,557	2,023	
	Basement	16612	2161		16547	2152	
	Crawl**	15144	1970		15056	1958	
2018 + 2021 ceiling insulation	Slab	15536	2021	0.5%	15,472	2,012	0.5%
	Basement	16521	2149	0.6%	16,451	2,140	0.6%
	Crawl**	15053	1958	0.6%	14,959	1,946	0.6%
2018 + 2021 slab insulation	Slab	14938	1943	4.3%	14,877	1,935	4.3%
	Ave for CZ					1,936	
2018 + 2021 wall cont. insulation	Slab						
	Basement						
	Crawl**						
2018 + 2021 window U-Factor	Slab	15566	2024	0.3%	15,501	2,016	0.3%
	Basement	16553	2154	0.3%	16,489	2,145	0.3%
	Crawl**	15091	1963	0.4%	14,994	1,951	0.4%
2021 without efficiency options	Slab	14,408	1,874	7.7%	14,344	1,866	7.8%
	Basement	15,903	2,068	4.3%	15,832	2,059	4.3%
	Crawl**	14,610	1,900	3.6%	14,519	1,889	3.5%
2021 + HVAC option	Slab	13,485	1,754	13.6%	13,450	1,749	13.5%
	Basement	14,824	1,928	10.8%	14,786	1,924	10.6%
	Crawl**	13,561	1,765	10.4%	13,502	1,756	10.3%
2021 + Water Heater option	Slab	13,277	1,726	15.0%	13,212	1,718	15.1%
	Basement	14,742	1,916	11.3%	14,669	1,907	11.4%
	Crawl**	13,470	1,752	11.1%	13,382	1,740	11.1%
2021 + Ventilation option	Slab	14,326	1,864	8.2%	14,259	1,855	8.3%
	Basement	15,727	2,046	5.3%	15,651	2,036	5.4%
	Crawl**	14,446	1,879	4.6%	14,346	1,867	4.6%
2021 + Duct option	Slab	13,816	1,797	11.5%	13,749	1,788	11.6%
	Crawl**	14,273	1,857	5.7%	14,174	1,844	5.8%

*Cost savings ($/yr) relative to 2018 baseline
**Crawl: vented CZ 3-4; conditioned CZ 5-7

Configuration		Annual Energy Use CZ 4 Baltimore Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*
2018 Baseline	Slab	8,262	697	1,807	
	Basement	9,848	696	2,012	
	Crawl**	8,669	665	1,826	
2018 + 2021 ceiling insulation	Slab	8,244	690	1,797	0.6%
	Basement	9,833	689	2,003	0.4%
	Crawl**	8,652	659	1,818	0.4%
2018 + 2021 slab insulation	Slab	8,180	674	1,772	1.9%
	Ave for CZ			1,772	
2018 + 2021 wall cont. insulation	Slab	8,177	661	1,758	2.7%
	Basement	9,763	660	1,964	2.4%
	Crawl**	8,590	629	1,778	2.6%
2018 + 2021 window U-Factor	Slab	8,256	687	1,796	0.6%
	Basement	9,848	686	2,002	0.5%
	Crawl**	8,666	656	1,816	0.5%
2021 without efficiency options	Slab	7,673	626	1,655	8.4%
	Basement	9,159	649	1,873	6.9%
	Crawl**	8,174	616	1,711	6.3%
2021 + HVAC option	Slab	7,348	565	1,550	14.2%
	Basement	8,795	580	1,753	12.9%
	Crawl**	7,761	552	1,590	12.9%
2021 + Water Heater option	Slab	7,670	604	1,624	10.1%
	Basement	9,188	617	1,835	8.8%
	Crawl**	8,171	594	1,678	8.1%
2021 + Ventilation option	Slab	7,931	586	1,648	8.8%
	Basement	9,481	584	1,847	8.2%
	Crawl**	8,420	575	1,700	6.9%
2021 + Duct option	Slab	7,495	581	1,585	12.3%
	Crawl**	7,732	607	1,644	10.0%

*Cost savings ($/yr) relative to 2018 baseline
**Crawl: vented CZ 3-4; conditioned CZ 5-7

Configuration		Annual Energy Use CZ 5 Chicago Frame Wall Natural Gas (60%) kWh/yr	thrm/yr	$/yr	Savings*
2018 Baseline	Slab	7635	1098	2156	
	Basement	9,297	1,089	2,355	
	Crawl**	7,720	999	2,054	
2018 + 2021 ceiling insulation	Slab	7,691	1,090	2,146	0.5%
	Basement	9,285	1,080	2,343	0.5%
	Crawl**	7,702	991	2,043	0.5%
2018 + 2021 slab insulation	Slab	7,647	1,071	2,120	1.7%
	Ave for CZ				
2018 + 2021 wall cont. insulation	Slab	7,617	1,049	2,093	2.9%
	Basement	9,209	1,040	2,291	2.7%
	Crawl**	7,635	952	1,993	3.0%
2018 + 2021 window U-Factor	Slab				
	Basement				
	Crawl**				
2021 without efficiency options	Slab	7,142	1,018	1,999	7.3%
	Basement	8,614	1,037	2,210	6.2%
	Crawl**	7,216	947	1,934	5.8%
2021 + HVAC option	Slab	6,770	898	1,824	15.4%
	Basement	8,209	914	2,029	13.8%
	Crawl**	6,838	837	1,769	13.9%
2021 + Water Heater option	Slab	7,169	1,002	1,977	8.3%
	Basement	8,655	1,007	2,175	7.6%
	Crawl**	7,245	929	1,910	7.0%
2021 + Ventilation option	Slab	7,400	966	1,978	8.3%
	Basement	8,927	960	2,170	7.9%
	Crawl**	7,482	901	1,921	6.5%
2021 + Duct option	Slab	7,022	929	1,889	12.4%
	Crawl**				

*Cost savings ($/yr) relative to 2018 baseline
**Crawl: vented CZ 3-4; conditioned CZ 5-7

Configuration		Annual Energy Use CZ 6 Helena Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*	Annual Energy Use CZ 7 Duluth*** Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*
2018 Baseline	Slab	7,374	1,201	2,221		7,178	1,676	2,735	
	Basement	8,962	1,166	2,391		8,664	1,612	2,873	
	Crawl**	7,345	1,057	2,066		7,119	1,473	2,515	
2018 + 2021 ceiling insulation	Slab	7,359	1,192	2,210	0.5%	7,116	1,665	2,722	0.5%
	Basement	8,945	1,155	2,378	0.5%	8,649	1,599	2,857	0.6%
	Crawl**	7,333	1,047	2,054	0.6%	7,105	1,460	2,499	0.6%
2018 + 2021 slab insulation	Slab								
	Ave for CZ								
2018 + 2021 wall cont. insulation	Slab								
	Basement								
	Crawl**								
						CZ 7 2021 no HRV, for reference:			
2018 + 2021 window U-Factor	Slab					7,087	1,671	2,678	2.1%
	Basement					8,479	1,607	2,791	2.9%
	Crawl**					7,028	1,466	2,454	2.4%
2021 without efficiency options	Slab	6,970	1,198	2,165	2.5%	7,321	1,605	2,639	3.5%
	Basement	8,379	1,162	2,311	3.3%	8,787	1,523	2,743	4.5%
	Crawl**	6,937	1,052	2,008	2.8%	7,283	1,419	2,438	3.1%
2021 + HVAC option	Slab	6,586	1,054	1,964	11.6%	6,879	1,403	2,369	13.4%
	Basement	7,984	1,024	2,115	11.5%	8,344	1,333	2,486	13.5%
	Crawl**	6,583	930	1,833	11.3%	6,870	1,244	2,201	12.5%
2021 + Water Heater option	Slab	7,037	1,188	2,155	3.0%	7,400	1,600	2,635	3.7%
	Basement	8,441	1,135	2,282	4.6%	8,854	1,499	2,718	5.4%
	Crawl**	7,005	1,038	1,993	3.5%	7,353	1,409	2,429	3.4%
						CZ 7 2021 HRV .75 SRE v. .65:			
2021 + Ventilation option	Slab	7,198	1,126	2,120	4.5%	7,307	1,588	2,619	4.2%
	Basement	8,672	1,068	2,250	5.9%	8,772	1,502	2,719	5.4%
	Crawl**	7,189	995	1,980	4.2%	7,271	1,403	2,420	3.8%
2021 + Duct option	Slab	6,832	1,043	1,985	10.6%	7,210	1,409	2,418	11.6%
	Crawl**								

*Cost savings ($/yr) relative to 2018 baseline
**Crawl: vented CZ 3-4; conditioned CZ 5-7
***For CZ 7 all 2021 results include an HRV

Home Innovation
RESEARCH LABS™

→ Cost Effectiveness of the Residential Provisions of the 2021 IECC

January 2022

Table of Contents

Background

The International Code Council (ICC) updates their model building codes on a 3-year cycle. The latest version of their International Energy Conservation Code (IECC) is the 2021 IECC[1] and contains multiple updates, or code changes, to the 2018 IECC as a result of a public process administered by the ICC.[2]

The code changes from the 2018 to the 2021 IECC result in both increased energy savings and construction costs, and this analysis quantifies the resulting cost-effectiveness.

Following U.S. Department of Energy cost effectiveness certification of the 2021 IECC, the National Association of Homebuilders (NAHB) commissioned the Home Innovation Research Labs (HIRL) to conduct an independent cost analysis of the 2021 IECC. The report, *2021 IECC Residential Cost Effectiveness Analysis*[3] (HIRL report), was published in June 2021, and asserted that the 2021 IECC imposed builder compliance costs of nearly $12,000 and homeowner payback periods of up to 79 years, depending on climate zone. This analysis is intended to "check the math" of the NAHB report using current cost data and widely accepted cost effectiveness metrics. To enable an easy comparison this report mirrors the HIRL Report structure, section by section and table by table, and is accompanied by a short comparison document titled Comparison of 2021 IECC Residential Cost Effectiveness Analyses, which also identifies concerns and issues identified in the HIRL report that were addressed.

Methodology

This analysis relies on existing data and new research. The primary source is the HIRL report mentioned above.

The energy savings for this analysis were sourced directly from the HIRL report and are documented in Appendix E. Below is how the HIRL report describes how energy savings were developed.

> "The analysis for this study is based on a methodology[4] developed by Home Innovation (formerly NAHB Research Center) to calculate energy savings. This methodology defined a Standard Reference House, including the building configuration and energy performance parameters, that was originally used to report an analysis of the 2012 IECC code changes.[5]
>
> For analysis in this report, annual energy use costs were developed using BEopt[6] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency.[7] The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas."

The incremental costs of the code changes reported in the HIRL report were evaluated and updated. Material costs were generally updated to use publicly available sources from retailers and distributors, with sources shown in Appendix A. The majority of labor costs from the HIRL report were used and were developed using labor rates from RS Means.[8] Some code changes that contained a cost in the HIRL report were determined to result in no incremental cost after a review of the code change.

Cost-effectiveness was evaluated using the U.S. Department of Energy's *Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes* (DOE Methodology),[9] which is used when DOE conducts a determination analysis to evaluate whether the new edition of the IECC saves energy compared to its immediate predecessor. The HIRL report only considered simple payback, which is included in the DOE

1 https://codes.iccsafe.org/content/IECC2021P1
2 https://www.iccsafe.org/products-and-services/i-codes/code-development/
https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
4 Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012
5 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012
6 BEopt (Building Energy Optimization Tool) software https://beopt.nrel.gov/home
7 Energy Information Agency https://www.eia.gov/
8 https://www.rsmeans.com/
9 https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

methodology along with Life-cycle cost, which was added for this analysis. A description of the two metrics used in this analysis are shown below, as described by the DOE methodology:

- Life-Cycle Cost (LCC) is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. Any code change resulting in a net LCC less than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost effective. LCC is the primary metric DOE uses to evaluate cost-effectiveness.
- Simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc.

All costs and savings in this analysis are based on the model 2018 and 2021 IECC codes. When adopting codes many states and local jurisdictions implement amendments, often decreasing the stringency of codes. And as of January 2022, only 9 states (including Washington D.C.) have adopted a code equally stringent to the 2018 IECC.[10] Therefore for the remaining 42 states would realize greater energy savings, and likely be more cost-effective, than what is estimated in this analysis.

Standard Reference House

The building geometry in Table 1 utilized in this analysis is specified in the HIRL report and was originally for a representative single-family detached home using Home Innovation's 2009 Annual Builder Practices Survey (ABPS). The parameters are average values from the ABPS for non-IECC-mandated building areas and features. Based on Home Innovation's 2019 ABPS, the geometry was revised. The floor, attic, wall, and window areas used in the Standard Reference House for this study are shown in Table 1.

Table 1 Average Wall and Floor Areas of the Reference House

Reference House Component	Area (SF)
1st floor conditioned floor area (CFA)	1,875
2nd floor CFA	625
Total CFA without conditioned basement	2,500
Foundation perimeter, linear feet (LF)	200
Slab/basement/crawl floor area	1,875
Total CFA with conditioned basement	4,375
Ceiling area adjacent to vented attic	1,875
1st floor gross wall area (9' height)	1,800
2nd floor gross wall area (8.75' height)	875
Total above grade wall area (excludes rim areas)	2,675
Basement wall area (8' height; 2' above grade)	1,600
Crawlspace wall area (4' height; 2' above grade)	800
Window area (15% of CFA above grade)	375

[10] Source: https://www.energycodes.gov/status/residential

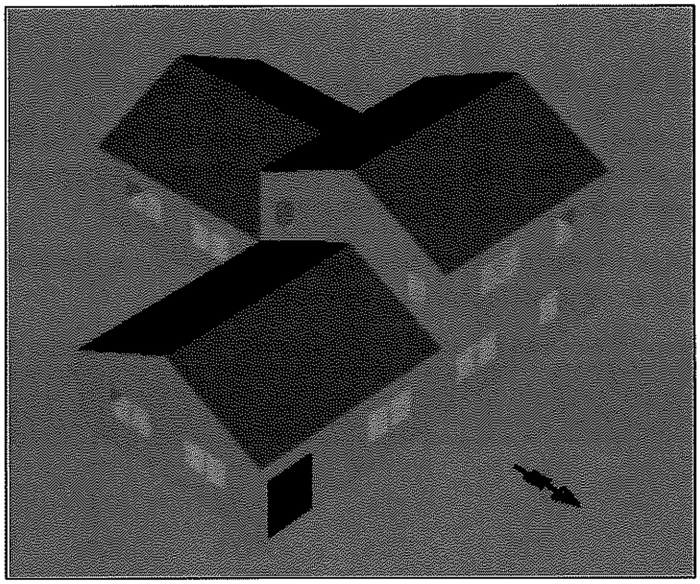

Figure 1 Simulation Model of Standard Reference House

Representative Locations

Energy savings were quantified using six representative locations in climate zones (CZs) 2 through 7, as shown in Table 2.

Table 2 Representative Locations

Climate Zone	2	3	4	5	6	7
City	Phoenix	Memphis	Baltimore	Chicago	Helena	Duluth
State	Arizona	Tennessee	Maryland	Illinois	Montana	Minnesota
Moisture Region	Dry	Moist	Moist	Moist	Dry	n/a
HDD65*	1,050	2,960	4,600	6,330	7,660	9,570
CDD65*	4,640	2,110	1,233	842	317	162
**Daily Average Weather Data (TMY). Source: Residential Energy Dynamics, redcalc.com*						

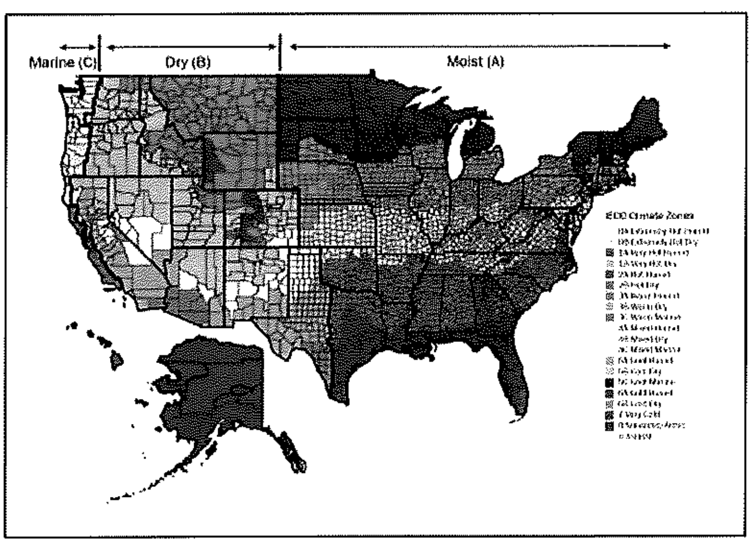

Figure 2 DOE Climate Zone Map

Configurations and Weighted Averaging

Results in this analysis (e.g., costs, savings, economic metrics) have been weighted by wall type, foundation type, for each climate zone, and by each location to result in a national weighted average. The data in Table 3 was used for these weightings and is based on the 2019 ABPS.

Only one heating fuel was used for each location based on the predominant fuel in the climate, and the heating and domestic hot water equipment use the same fuel.

Table 3 Construction Data. Source: adapted from Home Innovation's 2019 ABPS

Climate Zone	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Primary Heating Fuel	Electric	Electric	Gas	Gas	Gas	Gas
Mass Wall	30%	10%	n/a	n/a	n/a	n/a
Frame Wall	70%	90%	100%	100%	100%	100%
Slab	100%	75%	20%	15%	5%	30%
Cond. Basement	n/a	10%	60%	70%	90%	5%
Vented Crawlspace	n/a	15%	20%	n/a	n/a	n/a
Cond. Crawlspace	n/a	n/a	n/a	15%	5%	65%
Housing Starts	28%	28%	21%	17%	5%	1%

HVAC and Water Heating Equipment

The refence house is configured with equipment meeting the current DOE energy-efficiency standards as shown in Table 4. When an 'additional efficiency package option' from the 2021 IECC would require more efficient equipment the equipment in Table 5 was used.

Table 4 Standard Efficiency Equipment

Reference House	Equipment
Gas	80 AFUE gas furnace + 13 SEER air conditioner (CZ 5-7) or 14 SEER (CZ 4)
	40 gallon gas natural draft water heater, 0.58 UEF
Electric	14 SEER/8.2 HSPF air source heat pump
	50 gallon electric water heater, 0.92 UEF

Table 5 High Efficiency Equipment Options

Reference House	Equipment
Gas	95 AFUE gas furnace + 16 SEER air conditioner
	Tankless gas direct vent water heater, 0.82 UEF
Electric	16 SEER/10 HSPF heat pump
	Heat pump water heater, 50 gal, 2.0 EF

Changes for 2021

The 2021 IECC contains changes relative to the 2018 IECC that will result in increased energy savings, and increased construction costs. Appendix A contains a complete list of code changes that were evaluated for this analysis, but the most significant changes include:

- Improved envelope requirements (See Appendix D)
  - Increased ceiling insulation in climate zones 2 through 8
  - Continuous insulation on above-grade walls in climate zones 4 and 5
  - Slab insulation in climate zones 3 through 5
  - Lower window U-factor in climate zones 3 and 4
- Higher efficacy lighting
- Increased fan efficacy, and testing requirements
- Balanced ventilation (ERV/HRV) in climate zones 7 and 8
- One of five 'additional efficiency package options' (See RE209 in Appendix A for details):
  - Enhanced envelope performance option[11]
  - More efficient HVAC equipment performance option
  - Reduced energy use in service water-heating option
  - More efficient duct thermal distribution system
  - Improved air sealing and efficient ventilation option

Some homes meet the requirements of the additional efficiency package options due to construction practices (i.e., ducts located in conditioned space for homes with basements and conditioned crawlspaces), or code requirements (i.e., ERV/HRV required in climate zones 7 and 8). For these homes, no changes are needed to meet this requirement, but for others a change will need to be made and it will result in additional costs and savings.

All code changes that were reflected in the energy models are noted in Table 6.

Results

Construction Costs

The incremental construction costs considered in this analysis are shown in Table 6, with details in Appendix A and B. The weighted average incremental construction cost is shown in Table 7.

Table 6 Incremental Construction Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZs	Reference House
RE7*	Lighting: revised definition of high-efficacy	All	$0
RE18/20/21	Certificate: additional info	All	$0
RE29*	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742
	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680
RE32*	Slab edge: NR to R10/2 (CZ3)	3	$709
	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709
RE33*	Ceiling insulation R38 to R49	2-3	$226
RE36*	Ceiling insulation R49 to R60	4-7	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	$0

[11] The enhanced envelope option was not evaluated for this study.

RE35*	Windows: reduces U-value from 0.32 to 0.30	3-4	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6
RE72	Air seal narrow framing cavities	All	$0
RE82	Air seal rim (basement; unvented crawlspace)	All	$0
	Air seal rim (slab, vented crawlspace)	All	$0
RE96	House tightness, allows trade-off for performance path	All	$0
RE103	Air seal electrical & communication outlet boxes	All	$0
RE106	Thermostat: requires 7-day programming	All	$0
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31
RE133*	Updates ventilation fan efficacy (affects bath EF)	All	$0
RE139*	Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.)	7	$1,742
RE145*	Lighting: 100% high-efficacy; controls (slab)	All	$33
	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$41
RE148	Lighting, commercial	All	$0
RE151	Performance path backstop: 2009 IECC	All	$0
RE178	Performance path ventilation type to match proposed	All	$0
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	$0
RE209*	Additional efficiency package options:	All	
	HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline	5-7	$1,142
	HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline	4	$952
	HVAC, electric house, 10 HSPF/18 SEER heat pump	All	$2,566
	Water Heater, gas house, tankless direct-vent, 0.82 UEF	All	$549
	Heat Pump Water Heater, electric house, 50 gal, 2.0 EF	2-3	$1,178
	Ventilation, gas house	4-7	$1,707
	Ventilation, electric house	3-5	$1,707
	Ventilation, electric house with improved air tightness	2	$2,057
	Duct, slab house, buried ducts in attic	2-3	$2,374
	Duct, slab house, buried ducts in attic	4-7	$658
	Duct, vented crawlspace house	3	($809)
	Duct, vented crawlspace house	4	($36)

***Indicates a code change that was included in the energy modeling analysis for this study (10 total)**

Table 7 Incremental Construction Cost for 2021 Reference House, weighted averages

Total Incremental Cost	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Without additional efficiency package options	$1,373	$297	$902	$2,254	$3,102	$321	$2,050
With HVAC option	$3,273	$2,864	$3,469	$3,206	$4,245	$1,464	$3,192
With Water Heater option	$2,274	$1,475	$2,080	$2,803	$3,651	$870	$2,599
With Ventilation option	$3,161	$2,354	$2,609	$3,961	$4,809	$2,028	$2,050
With Duct option, slab house	$3,243	$2,672	$3,447	$3,444	$4,315	$926	$2,669
With Duct option, vented crawlspace house	n/a	n/a	-$437	$2,049	n/a	n/a	n/a

Table 8 contains code changes that were not included in this analysis either because they are unlikely to impact many homes or would result in some energy savings but their impacts were not modeled.

Table 8 Potential Additional Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE47	Attic pull-down stair: adds exception to insulation requirements	2-3	($87)
	Same	4	($113)
RE49	Baffles at tray ceiling (example)	2-3	$125
	Same	4-7	$157
RE52	Walls: removes exception for reduced c.i. at WSP	3-7	$1,283 to $2,692
RE55	Adds requirements for unconditioned basements	4-5	$97
RE109	Floor insulation for ducts in conditioned space: min R19	2	$34
RE134	Adds min efficacy for air handlers if integrated w/ventilation	All	$1,115
RE149	Lighting: exterior controls	All	$22

Energy Use Costs and Savings

Modeled energy costs are shown in Table 9, and savings in Table 10, both as weighted averages. Complete energy use data for all homes modeled is in Appendix E.

Table 9 Annual Energy Use Cost for Reference House, weighted averages

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,129	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
slab houses only	$2,074	$2,224	$2,025	$1,807	$2,156	$2,222	$2,735
vented houses only			$1,960	$1,827			
2021 without additional efficiency package options	$2,015	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
2021 with HVAC option	$1,881	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$1,922	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$1,993	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$1,852	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace house			$1,845	$1,644			

Table 10 Energy Cost Savings relative to 2018 Baseline Reference House

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	5.3%	2.8%	6.8%	7.1%	6.2%	3.3%	3.3%
2021 with HVAC option	11.6%	8.0%	12.8%	13.1%	14.1%	11.5%	12.8%
2021 with Water Heater option	9.7%	8.7%	14.1%	8.9%	7.6%	4.5%	3.6%
2021 with Ventilation option	6.4%	3.6%	7.5%	8.1%	7.7%	5.7%	n/a
2021 with Duct option, slab house	10.7%	8.0%	11.6%	12.3%	12.3%	10.6%	11.6%
2021 with Duct option, vented crawlspace house			5.8%	10.0%			

Cost Effectiveness

Cost effectiveness is calculated based on the data in Table 7 and Table 9 using the metrics described previously.

Table 11a summarizes the simple payback relative to the 2018 IECC, these results are informative, but Table 11b summarizes the weighted LCC cost for the various configurations of 2021 IECC compared to the 2018 IECC, which is more indicative of the cost-effectiveness of the 2021 IECC.

Table 11a Simple Payback relative to 2018 Baseline Reference House, years

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	11	5	6	16	22	4	25
2021 with HVAC option	14	16	13	13	13	5	10
2021 with Water Heater option	12	8	7	16	21	8	28
2021 with Ventilation option	24	29	18	26	28	15	20
2021 with Duct option, slab house	15	15	15	16	16	4	8
2021 with Duct option, vented crawlspace house			0	11			

In Table 11b, and for other LCC results, a negative LCC indicates a net savings, and a cost-effective code change. The packages which have a negative LCC have cells with blue text and show that in each location analyzed there are multiple cost-effective options with the structure of the 2021 IECC. Additionally, the cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406) which have more flexibility in the measures a builder can use in their homes. The results show that construction based on the 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones.

Table 11b LCC* relative to 2018 Baseline Reference House ($ / house)

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	(1,625.67)	(1,350.06)	(2,783.91)	(1,318.71)	(690.87)	(1,757.92)	**1,411.09**
2021 with HVAC option	(1,932.88)	(180.50)	(1,710.75)	(2,728.63)	(3,300.21)	(4,796.20)	(2,947.04)
2021 with Water Heater option	(2,590.72)	(2,963.03)	(4,790.45)	(1,295.80)	(550.40)	(1,507.53)	**2,131.96**
2021 with Ventilation option	**1,102.13**	**1,892.34**	(49.29)	**1,388.91**	**1,679.62**	(9.37)	**933.64**
2021 with Duct option, slab house	(2,670.47)	(2,199.57)	(2,958.79)	(2,324.45)	(2,612.12)	(5,121.73)	(3,784.46)
2021 with Duct option, vented crawlspace house	n/a	n/a	(3,688.02)	(2,759.88)	n/a	n/a	n/a

*Negative LCC indicates net savings

The HIRL report included an example of a comparison of savings for a gas and electric home in climate zone 3 in "Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline." However, the report did not publish the energy use data for individual gas homes in climate zone 3, so that comparison and the relative cost-effectiveness could not be evaluated in this analysis.

Cost Effectiveness of Selected Code Changes

Individual code changes were evaluated to show their costs, savings, and cost-effectiveness against the 2018 IECC baseline. For thermal envelope changes, Table 13 shows the incremental costs, Table 14 shows the associated modeled energy cost, and Table 15 shows the energy savings.

Table 13 Incremental Construction Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Ceiling insulation	$233	$233	$204	$204	$204	$204
Slab insulation	n/a	$709	$709	$709	n/a	n/a
Wall continuous insulation	n/a	n/a	$1,742	$2,680	n/a	n/a
Window U-factor	n/a	$67	$67	n/a	n/a	n/a

Table 14 Annual Energy Use Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
2018 baseline, slab houses only		$2,025	$1,807	$2,156		
2018 + 2021 ceiling insulation	$2,216	$2,017	$1,925	$2,269	$2,353	$2,584
2018 + 2021 slab insulation, slab houses only	n/a	$1,936	$1,773	$2,120	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	$1,886	$2,217	n/a	n/a
2018 + 2021 window U-factor	n/a	$2,021	$1,924	n/a	n/a	n/a

Table 15 Energy Cost Savings of Thermal Envelope Changes relative to 2018 Baseline Reference House

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	0.3%	0.6%	0.5%	0.5%	0.6%	0.6%
2018 + 2021 slab insulation, slab houses only	n/a	4.5%	1.9%	1.6%	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	2.5%	2.7%	n/a	n/a
2018 + 2021 window U-factor	n/a	0.4%	0.5%	n/a	n/a	n/a

Using the data above, the cost-effectiveness of the thermal envelope changes was evaluated with results in Table 16. Additionally, Table 17 contains data on the cost effectiveness of an HRV in climate zone 7. The data shows that some measures are cost-effective and some are not for the homes modeled. There are several key takeaways from these results.

- Individual code changes to the 2018 IECC may not be cost-effective by themselves, but the overall result for the 2021 IECC is that it is cost-effective (as shown in Table). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

Table 16 Simple Payback relative to 2018 Baseline Reference House for Thermal Envelope Changes, years

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	31	20	22	19	15	14
2018 + 2021 slab insulation, slab houses only	n/a	8	20	20	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	36	43	n/a	n/a
2018 + 2021 window U-factor	n/a	9	6	n/a	n/a	n/a

Table 17 Cost effectiveness of HRV in CZ 7

	CZ 7 Duluth
Incremental cost of HRV	$1,742
Annual energy cost, 2021* without HRV	$2,539
Annual energy cost, 2021* with HRV	$2,514
Energy cost savings for HRV	1.0%
Simple payback years	12
*Without additional efficiency package options	

The 2021 IECC requires one of five 'additional efficiency package options' (See RE209 in Appendix A for details). The cost-effectiveness of these were evaluated based on data in Table 18 and Table 19, with results in Table 20, and Table 21.

Table 18 Incremental Construction Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	$1,900	$2,567	$2,567	$952	$1,143	$1,143
Water Heater option	$901	$1,178	$1,178	$549	$549	$549
Ventilation option	$1,788	$2,057	$1,707	$1,707	$1,707	$1,707
Duct option, slab house	$1,870	$2,374	$2,545	$1,190	$1,213	$605
Duct option, vented crawlspace house			($1,339)	($205)		

Table 19 Annual Energy Use Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options, all houses	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
slab houses only	$2,163	$1,867	$1,656	$1,999	$2,166	$2,639
vented houses only	n/a	$1,890	$1,711	n/a	n/a	n/a
2021 with HVAC option	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace	n/a	$1,845	$1,644	n/a	n/a	n/a

Table 20 shows the savings of the additional efficiency package options relative to the base 2021 code. The packages were designed to achieve roughly 5% additional savings, and in this analysis the savings ranged from 0.4% to 9.9%, with an average of 4.4%.

Table 20 Energy Cost Savings of Additional Efficiency Package Options relative to 2021 without packages

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	5.4%	6.4%	6.5%	8.3%	8.5%	9.9%
Water Heater option	6.2%	7.8%	2.0%	1.5%	1.2%	0.4%
Ventilation option	0.9%	0.7%	1.1%	1.6%	2.5%	0.8%
Duct option, slab house	5.4%	4.1%	4.3%	5.5%	8.4%	8.4%
Duct option, vented crawlspace house	n/a	2.4%	3.9%	n/a	n/a	n/a

Table 21 shows the cost-effectiveness of each additional efficiency package option relative to the base 2021 IECC. This data by itself does not provide meaningful conclusion because it uses the 2021 IECC as a baseline, and the efficiency package options along with all the other code changes collectively achieve savings beyond the 2018 IECC. However, it can be used to infer the relative cost-effectiveness of each of these options. Table 11 can be used to make the same comparison, and as mentioned previously builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).

Table 21 Simple payback of efficiency package options relative to 2021 house without packages, years

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	21.8	21.3	8.1	6.4	5.8	4.6
Water Heater option	8.8	8.0	15.3	17.9	21.2	75.3
Ventilation option	109.7	134.9	109.8	60.5	30.3	0.0
Duct option, slab house	20.5	30.7	9.3	6.0	3.6	3.0
Duct option, vented crawlspace house	n/a	0.0	0.0	n/a	n/a	n/a

Conclusions

The HIRL report was analyzed and updated with new costs for code changes based on publicly available sources, and cost-effectiveness was re-examined using metrics from the DOE Methodology that is used to evaluate the cost-effectiveness of code changes (i.e., Life-Cycle Cost). Key findings from this analysis are:

- The 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones, and there are multiple cost-effective compliance options in each climate zone.
- The cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).
- There are significant savings relative to the 2018 IECC, ranging from a national average of 6.4% to 11.6%, depending on which additional efficiency package option is assumed.
- The weighted national average incremental cost of the code changes ranges from $2,695 to $3,694 depending on which additional efficiency package option is assumed.
- Individual code changes to the 2018 IECC have varying ranges of simple payback, but overall, the 2021 IECC is cost-effective as a package of measures that work together to achieve significant cost-effective savings (as shown in Table 11b). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

Code changes are summarized below along with their estimated incremental costs. This analysis evaluated and updated the incremental costs of the code changes reported in the HIRL report. Material costs were generally updated to use publicly available sources from retailers and distributors in November 2021, with sources shown in footnotes. When the same product was available from multiple retailers, the least cost option was used as a source because a builder has higher purchasing power and like likely to purchase many products at a lower price due to their bulk purchasing power. Even with this approach the material costs used in this report are likely to be higher than what a builder would pay, therefore producing conservative results. Unless noted, the majority of labor costs from the HIRL report were used and were sourced from hour estimates and labor rates from RS Means.[12] Some code changes that the HIRL report contained a cost were determined to result in no incremental cost after a review of the code change, and those are noted as well.

The total cost to the builder has a 17.5% markup applied to reflect the builder's gross profit margin and therefore the cost to the consumer. Many aspects of homebuilding are subcontracted out, so individual costs for labor, materials have markups applied by the subcontractor with a markup of 10% on material and equipment and 17.5% on labor, the columns marked "w/O&P" include these markups. To reflect that the majority, but not all, aspects of homebuilding are subcontracted out a factor of 79.3% is applied to these subcontractor markups to reflect the average share of construction costs that are subcontracted dating back to 2012.[13] The 10% markup is based on RS Means assumptions,[14] and the 17.5% markup is based on an average gross profit margin for homebuilders over multiple years, with a low of 14.4% in 2008, a high of 20.8% in 2006, and with 18.3% as the most recent value from 2020.[15, 16]

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of Code Change:

This code change revises the definition of high-efficacy lighting to reflect current lighting market conditions more accurately. Previously the definition used the following for efficacy requirements:

1. 60 lumens per watt for lamps over 40 watts.
2. 50 lumens per watt for lamps over 15 watts to 40 watts.
3. 40 lumens per watt for lamps 15 watts or less.

Now the definition uses 65 lumens per watt, or 45 lumens per watt for luminaires.

Cost Implication of the Code Change

This code change does not impact the cost of construction because CFL and LED lighting that was being used to meet the definition of 'High-Efficacy' already exceeded the new requirements. Therefore, no cost impact is assumed for the reference home.

12 https://www.rsmeans.com/
13 Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf
14 Source: https://www.rsmeans.com/resources/articles/what-is-construction-estimating
15 Source: https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/
16 Source: https://www.coconstruct.com/blog/despite-turbulent-2020-home-builder-profit-margins-grew-3-5-yoy

RE18, RE20, RE21

Reference Code Section

R401.3 Certificate

Summary of Code Change:

This code change requires additional information on the certificate for the home. RE18 requires information for onsite renewable systems (e.g., capacity). RE20 requires additional information on the certificate about the builder, code edition, and compliance path. RE21 requires additional information about insulation and ERI scores.

Cost Implication of the Code Change

The code change proposal will not increase or decrease the cost of construction. The administrative change of reporting additional, readily-available, information on a certificate that is already produced takes no additional time for a builder or rater. Therefore, no cost impact is assumed for the reference home.

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of Code Change:

This code change increases insulation required in above-grade walls in climate zones 4 and 5 to match existing requirements in climate zone 6.

Cost Implication of the Code Change

This code change will increase the cost of construction for all homes in climate zones 4 and 5. For 2x4 walls the cost is based on an increase from R-13+5 to R-13+10, and for 2x6 walls the cost is based on an increase from R-20 to R-20+5. A weighted average of these two costs is used in the analysis based on data collected by the U.S. DOE's Residential Energy Code Field Studies for homes built in climate zones 4 and 5.

Cost to add information to the certificate, Climate zone 4

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	73%	$810.20
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	27%	$931.90
Total to Consumer				$1,742.10

Cost to add information to the certificate, Climate zone 5

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	32%	$360.58
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	68%	$2,319.88
Total to Consumer				$2,680.46

Cost to increase c.i. from R5 to R10 for 2x4 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(2,300)	($2,921.81)
XPS, 15 psi, 2", R10[19]	SF	$1.04	$0.49	$1.53	$1.68	2,300	$3,868.29
Total to Builder							$946.48
Total to Consumer							$1,112.07

Cost to increase c.i. from none to R5 for 2x6 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	2,300	$2,921.81
Total to Builder							$2,921.81
Total to Consumer							$3,433.00

17 Source: https://www.energycodes.gov/residential-energy-code-field-studies

18 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-5-polystyrene-foam-board-insulation-1-x-4-x-8/565243/p-1444450471646-c-5779.htm?tid=4167156398492965668&ipos=3

19 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/654957/p-1444450471145-c-5779.htm?tid=-9057347254943865747&ipos=6

RE32

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change increases slab insulation in climate zones 3, 4 and 5 specified by Table R402.1.3. Climate zone 2 is increased from no insulation to R-10, for a depth of 2 ft. Climate zones 4 and 5 are increased from R-10 for a depth of 2 ft, to R-10 for a depth of 4 ft.

Cost Implication of the Code Change

This code change will increase the cost of construction by requiring more slab insulation to be installed in climate zones 3, 4, and 5. All climate zones will require an additional 400 sq. ft. of R-10 extruded polystyrene (XPS) slab insulation because the slab perimeter is 200 sq. ft. and the additional slab edge depth is an additional 2 ft.

Cost of additional slab edge insulation, CZ 3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10[20]	SF	$0.98	$0.40	$1.38	$1.51	400	$603.28
Total to Builder							$603.28
Total to Consumer							$708.83

Cost of additional slab edge insulation, CZ 4-5

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10[20]	$603.28	$0.98	$0.40	$1.38	$1.51	400	$654.65
Total to Builder							$603.28
Total to Consumer							$708.83

20 Source, https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/271000/p-1444450490132.htm

RE33, RE36

Reference Code Section

Table R402.1.2, Table R402.1.3, R402.2.1

Summary of Code Change:

This code change increases the ceiling insulation in climate zones 2 through 8 by a net of R-11. Climate zones 2 and 3 are increased to R-49 from R-38 by RE33, and climate zones 4 through 8 are increased to R-60 from R-49 by RE36.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 2 through 8. The cost is based on the incremental cost of blown cellulose in a vented attic and is assumed to be the same for both code changes, including the same labor and equipment costs. A portion of the attic will not be impacted by this code change because the full-height of the insulation cannot be achieved (i.e., at the eave). So, when the nominal R-value required increase from R-38 to R-49, only the area of the attic where the full R-38 was achieved previously will have improved performance, and an associated cost. Therefore, the areas below were adjusted to reflect this.

Cost to Increase ceiling insulation from R-38 to R-49

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-38 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1414)	($2,103.26)
R-49 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1414	$2,295.94
Total to Builder								$192.68
Total to Consumer								$226.39

Cost to Increase ceiling insulation from R-49 to R-60

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-49 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1235)	($1,837.33)
R-60 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1235	$2,005.65
Total to Builder								$168.32
Total to Consumer								$197.76

21 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1618640/p-1520836262471-c-5777.htm?tid=4198096187601806274&ipos=1

RE34

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change removed the exception for floor insulation R-value which allowed insulation sufficient to fill the cavity if it provided at least R-19. This exception only applied to climate zones 5 to 8.

Cost Implication of the Code Change

This code change can increase the cost of construction, by requiring more insulation, if the exception was being used. However, the reference house does not have floor insulation above unconditioned space. Therefore, no cost impact is assumed for the reference home.

RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change reduces the maximum U-factor for windows in CZ3 and 4 from 0.32 to 0.30. The change also adds a footnote that a maximum window U-factor of 0.32 shall apply in CZ 5 to 8 for buildings located at high elevations, or in regions with high wind.

Cost Implication of the Code Change

This code change will increase the cost of construction in CZ 3-4. EPA's ENERGY STAR program found that window prices vary widely, and thermal performance was not the primary driver of consumer prices, which makes it hard to develop a clear incremental cost for changes in window thermal performance. Several sources were consulted showing a wide range of estimated incremental costs for this code change. Four different window incremental cost model / methods were collected in this analysis to better understand it.

Various Sources for Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material
California Energy Commission[22]	SF	$0.15
ENERGY STAR Windows v7.0[23]	SF	$0.40
Department of Energy[24]	SF	$0.14
Energy Trust of Oregon[25]	SF	$0.58

The v6.0 ENERGY STAR window requirements, established in 2015, require a U-factor of 0.30 for the Noth-Central and South-Central climates, which generally align with climate zones 3 and 4.[26] Additionally, ENERGY STAR estimates the 2020 market penetration of windows at 84%.[27] Therefore for many builders there will be no incremental cost for the code change, but because that is not the case for all builders the lowest cost from the above sources will be used for this analysis.

Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental Cost of Window	SF	$0.14	$0.00	$0.14	$0.15	375	$56.67
Total to Builder							$56.67
Total to Consumer							$66.58

22 Source: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369
23 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%20I_Criteria%20Analysis%20Report.pdf
24 Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf
25 https://www.energytrust.org/wp-content/uploads/2019/02/Energy-Trust-of-Oregon-Windows-2018-Market-Research-final.pdf
26 Source: https://www.energystar.gov/sites/default/files/Windows_Doors_and_Skylights_Program_Requirements%20v6.pdf
27 Source: https://www.energystar.gov/sites/default/files/asset/document/2020%20USD%20Summary%20Report_Lighting%20%20EVSE%20Update.pdf

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change revised the climate zone 5 glazed fenestration SHGC to 0.40, where there previously was no requirement.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Data provided by the ENERGY STAR program shows that many windows meeting the climate zone 5 U-factor requirement of 0.30, meet a SHGC of 0.40.[28] Additionally, if a home was complying with code through the Total Building Performance Option (Section R405), a 0.40 SHGC would have been used for modeling where there was no requirement. Therefore, no cost impact is assumed for the reference home.

28 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change does not add any new requirements, instead it separates prescriptive and mandatory provisions into separate sections.

Cost Implication of the Code Change

There is no direct cost implication from this code change because it does not add any new requirements. However, the cost of the additional ceiling insulation required in all climate zones (RE33 and RE36) is reflected here where more insulation would be required on an attic access hatch. The cost is based on securing an additional 3" of EPS foam board to an attic access hatch.

Cost to increase the insulation above an attic access by R-11

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
EPS, 3" thick, R-12[29]	SF	$0.40	$0.40	$0.80	$0.89	6	$5.34
Total to Builder							$5.34
Total to Consumer							$6.28

29 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/expanded-polystyrene-foam-board-insulation-4-c-8/1632305/p-1444435978090.htm

RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds an exception attic pull-down stairs in CZ 0-4, which are not required to comply with the insulation level of the surrounding surfaces if the hatch meets:

- Average U-factor of 0.10 or R-value of R-13 or greater,
- 75% of panel area is insulated to R-13 or greater,
- Net area of the opening is less than 13.5 square feet, and
- The permitter is weather-stripped.

Cost Implication of the Code Change

This code change may decrease the cost of construction but is likely to have no impact on costs in most cases. No cost impact is assumed for the reference home, however, these costs are shown below for illustrative purposes.

Cost savings to reduce insulation above attic pull-down stair for CZ 2-3 (R49 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer) [18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (five 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(67.5)	($113.53)
Total to Builder							($73.67)
Total to Consumer							($86.56)

Cost savings to reduce insulation above attic pull-down stair for CZ 4 (R60 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer)[18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (six 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(81)	($136.23)
Total to Builder							($96.38)
Total to Consumer							($113.24)

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds a requirement to prevent loose-fill insulation in the attic from spilling from higher to lower sections with a baffle or retainer.

Cost Implication of the Code Change

This code change may increase the cost of construction where there is variation in the ceiling / attic height, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. illustrate this potential cost, the incremental cost of the insulation and the baffle is shown below. No cost is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to increase the height of insulation baffles at attic access hatch

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 3/4" CDX[30]	SF	$1.25	$0.60	$1.85	$2.03	4	$8.13
Total to Builder							$8.13
Total to Consumer							$9.56

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 2-3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX[31]	SF	$0.74	$0.52	$1.26	$1.40	76	$106.04
Total to Builder							$106.04
Total to Consumer							$124.59

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 4-8

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX[31]	SF	$0.74	$0.52	$1.26	$1.40	96	$133.95
Total to Builder							$133.95
Total to Consumer							$157.38

30 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/3-4-x-4-x-8-plywood-sheathing/1231162/p-1444431334153-c-13331.htm?tid=5612448418558004428ipos=1

31 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/1-2-x-4-x-8-plywood-sheathing-3-ply/1231085/p-1444431324783-c-13331.htm?tid=5612446418558004428ipos=6

RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced to result in a consistent sheathing thickness. The exception was limited to 40% of the gross wall area and by no more than R-3.

Cost Implication of the Code Change

This code change may increase the cost of construction where the exception was used, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. To illustrate this potential cost, the incremental cost of additional c.i. is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to install additional ½-inch thickness of continuous insulation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(1,065)	($2,038.92)
XPS, 15 psi, 1.5", R7.5[33]	SF	$1.03	$0.49	$1.52	$1.67	1,065	$2,680.45
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$1,091.99
Total to Consumer							$1,283.04

Cost to install OSB over entire wall and cover with 1- XPS

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
OSB, wall, 1/2"[36]	SF	$0.60	$0.44	$1.04	$1.15	1,065	$1,840.91
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$2,291.37
Total to Consumer							$2,692.26

32 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-3-polystyrene-foam-board-insulation-1-2-x-4-x-8/452873/p-1444450501960-c-5779.htm?cid=849541244764583270&ipos=4

33 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-7-5-polystyrene-foam-board-insulation-1-1-2-x-4-x-6/654955/p-1444450473323-c-5779.htm?cid=849541244764583270&ipos=7

34 Source: https://www.homedepot.com/p/Grip-Rite-11-x-2-in-Electro-Galvanized-Steel-Roofing-Nails-30-lb-Pack-2EGRFG!8/100114825?MERCH=REC-_-searchViewed-_-NA-_-100114825-_-N&

35 Source: https://www.fastenal.com/products/details/0226959

36 Source: https://www.menards.com/main/building-materials/panel-products/osb-sheathing/1-2-x-4-x-8-osb/1242309/p-1444422395209-c-13330.htm?cid=833673182255462379&ipos=2

RE55

Reference Code Section

R402.2.8 Basement walls

Summary of Code Change:

This code change adds requirement for how to insulate and seal unconditioned basements. It includes insulating at the floor overhead, walls surrounding the stairway, door(s) leading to the basement from conditioned space. It also states that no uninsulated duct, domestic hot water or hydronic heating surfaces may be exposed to the basement, and no HVAC supply or return diffusers may serve the basement.

Cost Implication of the Code Change

This code change may increase the cost of construction for a home with unconditioned basement. To illustrate this potential cost, this analysis develops a cost to increase c.i. in the walls surrounding the stairway. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to increase wall insulation in the stairway

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(200)	($254.07)
XPS, 15 psi, 2", R10[19]	SF	$1.04	$0.49	$1.53	$1.68	200	$336.37
Drywall screw, 2.5"[37]	LB	$1.59		$1.59	$1.72	(1.3)	($2.23)
Drywall screw, 3.5"[38]	LB	$1.59		$1.59	$1.72	1.6	$2.75
Total to Builder							$82.82
Total to Consumer							$97.31

37 Source: https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-8-x-2-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2557/p-1444441860201.htm

38 https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-10-x-3-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2735/p-1444441853388.htm

RE72

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of Code Change:

This code change clarifies that "Narrow cavities, of an inch or less, not able to be insulated, shall be air sealed."

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Narrow cavities are likely to already be air sealed (e.g., with expanding foam) as part of a standard air sealing package to achieve the required air leakage rates in code. Additionally other air sealing criteria in this Table are likely to already cover "Narrow Cavities", for example "The space between framing and skylights, and the jambs of windows and doors, shall be sealed." Therefore, no cost impact is assumed for the reference home.

RE82

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of Code Change:

This code change clarifies requirements for rim joists, specifying that the air barrier provided must be air sealed to the sill plate and sub floor.

Cost Implication of the Code Change

This code change will not increase the cost of construction because it clarifies and states explicitly that the rim joist air barrier must be sealed, which was already included in the general requirement of this table that any breaks or joints in the air barriers must be sealed. Therefore, no cost impact is assumed for the reference home.

RE96

Reference Code Section

R402.4.1.2 Testing

Summary of Code Change:

This code change adds flexibility by making the mandatory air leakage 5.0 ACH50, therefore allowing some tradeoffs where 3.0 ACH50 was required before. Because the overall performance target, and prescriptive requirements are unchanged there is no impact on the overall efficiency.

Cost Implication of the Code Change

This code change will not impact the cost of construction because it only adds flexibility to meet the same level of performance and does not meaningfully impact the efficiency of a home. Therefore, no cost impact is assumed for the reference home.

RE103

Reference Code Section

R402.4.6 Electrical and communication outlet boxes (air-sealed boxes)

Summary of Code Change:

This code change adds a new section to define "air-sealed boxes" that are already required by Table R402.4.1.1 Air Barrier, Air Sealing and Insulation Installation. Specifically, for "Electrical/phone boxes on exterior walls" the table states "The air barrier shall be installed behind electrical and communication boxes. Alternatively, air-sealed boxes shall be installed" which is unchanged from the 2018 IECC.

The new section R402.4.6 adds that air sealed boxes must be tested and sealed per NEMA OS 4, essentially clarifying the intent of the requirement in Table R402.4.1.1

Cost Implication of the Code Change

This code change may increase the cost of construction if the requirements of Table R402.4.1.1 were misinterpreted or not met, and are now met with the clarification of the new section. Additionally, there are no changes to the assumed air leakage rate, which could be achieved by using air-sealed boxes as a detail. Therefore, no cost impact is assumed for the reference home.

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of Code Change:

This code change revises the weighted average maximum fenestration SHGC permitted using tradeoffs from Section R405 in climate zones 1 through 3 from 0.50 to 0.40.

Cost Implication of the Code Change

This code change is unlikely to impact the cost of construction because windows in climate zones 1 through 3 typically have much better SHGC than the backstop this code change revises. Therefore, no cost impact is assumed for the reference home.

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of Code Change:

This code change clarifies the required capabilities of a programmable thermostat. Specifically, this code change clarifies that programmable thermostats shall be capable of maintaining different temperature set points for different days of the week, where it only previously required different times of the day.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction, even though the code change does require additional capabilities of a programmable thermostat. A review of retailors shows that the lowest-priced programmable thermostat often meets the requirements of this code change, so no cost was assigned to this code change. [39] Therefore, no cost impact is assumed for the reference home.

39 Source: https://hvacdirect.com/braeburn-1-heat-1-cool-universal-programmable-thermostat.html

RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of Code Change:

This code change clarifies requirements for ducts to be considered in conditioned space based on location. For example, it clarifies that for ducts in floor cavities to be considered within conditioned space, they must have R-19 insulation between the duct and the unconditioned space.

Cost Implication of the Code Change

Generally, this code change will not increase the cost of construction. However, in climate zones 1 and 2 there potentially could be an increase in cost because the prescriptive floor insulation in those climate zones is R-13. To illustrate this potential cost the incremental cost of the insulation and moving to an oval duct is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost of increase floor insulation within joist bay from R-13 to R-19

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
R-13 unfaced fiberglass batt[40]	SF	$0.52	$0.42	$0.94	$1.04	(80)	($83.35)
R-19 unfaced fiberglass batt[41]	SF	$0.57	$0.49	$1.06	$1.17	80	$93.54
7" round metal duct[42]	LF	$2.77		$2.77	$2.99	(40)	($119.48)
7" oval metal duct[43]	LF	$3.19		$3.19	$3.45	40	$137.81
Total to Builder							$28.52
Total to Consumer							$33.51

40 Source: https://www.homedepot.com/p/Knauf-Insulation-R13-EcoBatt-Unfaced-Fiberglass-Insulation-Batt-3-1-2-in-x-16-in-x-96-in-15-Bags-691011/313646784
41 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748
42 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-30-gauge-round-metal-duct-pipe/1010724l/p-1444432223926.htm
43 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-oval-metal-duct-pipe/1107600/p-1444432220354.htm

RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of Code Change:

This code change removes an exception, and not requires total duct leakage testing for systems where ducts and air handlers are located entirely within the building thermal envelope. For these systems, a leakage limit of 8.0 cubic feet per minute per 100 square feet of conditioned floor area applies.

Cost Implication of the Code Change

This code change will increase the cost of construction for the subset of homes that have ducts in conditioned space, or for homes with conditioned basements and unvented crawlspaces in this analysis. The cost is estimated based on an estimated 30 minutes to conduct the test by a Rater already on site to conduct other tests, as estimated by the ENERGY STAR Multifamily New Construction Program.[44] It does not include any additional costs for additional sealing or re-testing if the system does not meet the leakage limits.

Estimated cost of the duct leakage test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.5	$40.00
Total to Builder							$40.00
Total to Consumer							$47.00

44 Source: https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/multifamily_national_page

RE130

Reference Code Section

R403.6.3 Testing (new)

Summary of Code Change:

This code change requires testing of mechanical ventilation systems to verify that they meet the minimum ventilation flow rates. An exemption exists for testing certain kitchen local ventilation systems.

Cost Implication of the Code Change

This code change will increase the cost of construction for all houses. Additional testing will need to be conducted by personnel already on-site conducting other tests (e.g., air leakage and duct leakage tests). The code change proposal was based on requirements of the ENERGY STAR program, which estimates testing will take 5 minutes per system by a rater.[45] The Reference House contains 3 bathrooms (with local mechanical ventilation), one kitchen (which may be exempted from testing if local ventilation is present), and potentially one whole-house mechanical ventilation system (if the existing bathroom ventilation system is not used as part of this system). Therefore, it is estimated that there will be 4 tests taking a total of 20 minutes of a Rater's time at a rate of $80 an hour.

Estimated cost of the mechanical ventilation test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.33	$26.67
Total to Builder							$26.67
Total to Consumer							$31.33

45 Source: Cost & Savings Document https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/national_page

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change updates the mechanical ventilation system fan efficacy to align with the ENERGY STAR v4.0 requirements established in 2015. For a bath fan rated < 90CFM the efficacy increased from 1.4 to 2.8 CFM/Watt, and for a bath fan rated ≥ 90 CFM the efficacy increased from 2.8 to 3.5 CFM/Watt.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. The reference house uses a bath fan for whole-dwelling mechanical ventilation rated at 90 CFM. A review of fans that meet this airflow rate on Home Depot shows that the least cost fan available is rated at 3.6 CFM/Watt, exceeding the 2021 IECC requirement.[46],[47] Further an analysis by DOE determined that there was no incremental cost because all fans on the market exceed these requirements according to the fans listed in the Home Ventilating Institute's database, and all ventilation fans reviewed at Home Depot showed efficacies well above the fan efficacy requirements in the 2021 IECC. [48] Therefore, no cost impact is assumed for the reference home.

46 Source. https://www.homedepot.com/b/Bath-Bathroom-Exhaust-Fans-Bath-Fans/N-5yc1vZc4kq?NCNI-5&searchRedirect=90%2520cfm%2520bath%2520fan&semanticToken=310r20400g22000100_202111181639429610972139167_us-east1-m01%20310r20400g22000100%20%3E%20rid%3A%7B8984 [illegible] cfm%20bath%20fan%7D%3Aqr&sortorder=asc&sortby=price

47 Source. https://cycloneragehoods.com/bath-fans/c90/

48 Source. https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf

RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change adds efficacy requirements for whole-dwelling mechanical ventilation systems that utilize the air-handler fan. Specifically, a minimum 1.2 cfm/watt.

Cost Implication of the Code Change

This code change may increase the cost of construction of central fan integrated supply ventilation systems, where there is ductwork bringing in outdoor air to the return. This change will not impact homes with exhaust ventilation. The cost is based on upgrading the furnace to a variable-speed furnace, from a multi-speed furnace to meet the required efficacy. For this type of system, when there is no call for heating or cooling the air handler blower fan my still operate to meet ventilation requirements, this will be accomplished through a controller, the controller could wither activate a separate fan (e.g., an existing bath exhaust fan), or activate the air handler to run to only provide ventilation needs. This code change does not require changes to the ventilation controls, which are already commonly used prior to this code change, but the costs are shown below for illustrative purposes.

Incremental cost of variable-speed furnace

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 AFUE, multi-speed[49]	EA	$852.00		$852.00	$919.59	(1)	($919.59)
Gas furnace, 80 AFUE, variable-speed[50]	EA	$1,421.00		$1,421.00	$1533.73	1	$1,533.73
Total to Builder							$614.14
Total to Consumer							$721.59

Cost of both variable-speed furnace and ventilator fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Furnace, total to Builder from above							$614.14
Air Cycler Controller[51]	EA	$150.50	$0.00	$150.50	$162.44	1	$162.44
Damper[52]	EA	$90.39	$0.00	$90.39	$97.56	1	$97.56
15-amp circuit, duplex outlet, 20' 14/2 NM[53]	EA	$6.82	$23.50	$30.32	$35.58	1	$35.58
Wire, 14/2, add 20'[54]	LF	$0.45	$1.37	$1.82	$1.97	20	$39.41
Total to Builder							$949.13
Total to Consumer							$1,115.18

49 Source: https://hvacdirect.com/goodman-60-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800603an.html
50 Source: https://hvacdirect.com/goodman-80-afue-60-000-btu-upflow-variable-speed-gas-furnace-gmvc80604bn.html
51 Source: https://www.aircycler.com/collections/shop/products/g2?variant=28939784
52 Source: https://www.homedepot.com/p/Leviton-15-Amp-Residential-Grade-Grounding-Duplex-Outlet-White-10-Pack-M24-05320-WMP/100055734
53 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZ14
54 Source: https://www.homedepot.com/p/Southwire-1-000-ft-14-2-Solid-Romex-SIMpull-CU-NM-B-W-G-Wire-28827401/202316473

RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of Code Change:

This code change adds a new section to require a heat or energy recovery ventilation (HRV or ERV) in climate zones 7 and 8. The equipment mush have a minimum sensible heat recovery efficiency of 65%.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 7 and 8. The cost is estimated based on the incremental cost of installing an ERV instead of an ENERGY STAR bath fan which would have provided whole-house mechanical ventilation, therefore there is some cost savings when downgrading the bath fan. The ERV includes fans which meet the required fan efficacy of 1.2 CFM/Watt, and also includes integrated controls to ensure minimum ventilation needs are met. It is assumed that he ERV will be integrated into the existing HVAC distribution, so limited new ductwork is required.

Cost to install an ERV

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[55]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[56]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[57]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[58]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[59]	EA	$36.37	$23.50	$59.87	$66.02	1	$66.02
Wire, 14/2, add 20'[60]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[61]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[62]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[63]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,483.02
Total to Consumer							$1,742.48

55 Source. https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362
56 Source. https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
57 Source. https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495
58 Source. https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate
59 Source. https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
60 Source. https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4W214
61 Source. https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
62 Source. https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935
63 Source. https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

RE145

Reference Code Section

R404.1 Lighting equipment; R404.2 Interior lighting controls (new)

Summary of Code Change:

This code change increases the percent of high efficacy lighting from 90% to 100% for permanently installed lighting fixtured, and also defines high-efficacy light sources as lamps with an efficacy not less than 65 lumens per watt, or luminaires with an efficacy of 45 lumens per watt. Additionally, it adds a requirement to provide lighting controls (e.g., a dimmer) for all permanently installed light fixtures except for bathrooms, hallways, exterior fixtures, fixtures designed for safety or security.

Cost Implication of the Code Change

The increase of high-efficacy lighting is unlikely to increase the cost of construction in most cases. The use of non-high-efficacy lamps (i.e., incandescent) is uncommon, and recent actions by the Department of Energy indicate a new Standard set at 45 lumens per watt is likely to be established per requirements of the Energy Policy and Conservation Act. [64] Additionally, when incandescent bulbs are available, there are often less expensive high-efficacy (CFL) options available. This is shown in the tables below, but to be conservative the net negative cost is not used in the analysis.

The additional cost of adding dimmer switches will increase the cost of construction, and this is estimated by including the cost of one dimmer for each room that is not-exempted from the requirement.

Cost of high-efficacy lamps and dimmer switches (slab)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	4	$35.92
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(4)	($7.64)
Total to Builder							$28.28
Total to Consumer							$33.23

Cost of high-efficacy lamps and dimmer switches (basement or crawl space)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	5	$44.90
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(5)	($9.55)
Total to Builder							$35.35
Total to Consumer							$41.53

64 https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0001
65 Source: https://www.lightbulbs.com/product/maxlite-01604
66 Source: https://www.lowes.com/pd/GE-Classic-60-Watt-Dimmable-A15-Light-Fixture-Incandescent-Light-Bulb-2-Pack/1000444103
67 Source: https://www.homedepot.com/p/Leviton-Trimatron-600-Watt-Single-Pole-Universal-Rotary-Dimmer-White-Light-Almond-R00-RNI06-0TW/301370402
68 Source: https://www.menards.com/main/electrical/light-switches-dimmers-outlets/light-switches/legrand-reg-trademaster-reg-15-amp-1-pole-toggle-light-switch/rc15lwcc24/p-1444451212422-c-6324.htm?irid=3681600139528539746&ipos=3

Quantities

Room	Lamps	Dimmer
Dining room	6	1
Kitchen	6	1
Breakfast	4	1
Family Room	2	1
Halls	2	0
Baths (3)	10	0
Bedrooms	0	0
Exterior	2	0
Basement	4	1
Crawlspace	4	0
Total, basement	36	5
Total, crawlspace	36	4
Total, slab	32	4
Additional lamps required	4	

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of Code Change:

This code change requires compliance with Section C405.4 of the IECC for connected exterior lighting for Group R-2, R-3, and R-4 buildings.

Cost Implication of the Code Change

This code change will not impact the cost of construction for homes constructed to the IRC. Therefore, no cost impact is assumed for the reference home.

RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of Code Change:

This code change requires controls on exterior lighting that exceeds 30 Watts.

Cost Implication of the Code Change

This code change will increase the cost of construction, and is estimated by installing two screw-in light sensing controls. No cost impact is assumed for the reference home because the energy savings impact was not modeled, however, these costs are shown below for illustrative purposes.

Cost of exterior lighting control with light sensor

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Control, 100-watt rated, screw-in type[69]	EA	$8.51		$8.51	$9.19	2	$18.37
Total to Builder							$18.37
Total to Consumer							$21.58

69 Source: https://www.homedepot.com/p/Westek-Dusk-to-Dawn-Light-Control-SLC5BCB-4/202524022#product-overview

RE151

Reference Code Section

R405.2 Simulated Performance Alternative - Mandatory Requirements

Summary of Code Change:

This code change establishes a thermal envelope backstop for the performance path of the 2009 IECC.

Cost Implication of the Code Change

Due to the significant increase in stringency of the 2021 IECC over the 2009 IECC this code change is unlikely to have an impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE178

Reference Code Section

Table R405.4.2

Summary of Code Change:

When using the performance compliance option, this code change updates the mechanical ventilation system type for the standard reference design to be the same as the proposed design.

Cost Implication of the Code Change

This code change will have no impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE209

Reference Code Section

R401.2.5 Additional energy efficiency (new); R408 Additional efficiency package options (new)

Summary of Code Change:

This code change creates a new requirement for an 'additional efficiency package options.' This is implemented in Section R401.2.5 by selecting one of five options for the prescriptive path, achieving an additional 5% savings in the performance or Energy Rating Index paths. The five options are:

1. Enhanced envelope performance option
   - Requires a 5% improvement in the total building thermal envelope UA, and weighted average SHGC.
2. More efficient HVAC equipment performance option
   - Requires a ≥ 95 AFUE gas furnace, and 16 SEER air conditioner, or ≥ 10 HSPF / 16 SEER air source heat pump, or ≥ 3.5 COP ground source heat pump.
3. Reduced energy use in service water-heating option
   - Requires a ≥ 0.82 EF fossil fuel service water heating system (i.e., a tankless water heater), or ≥ 2.0 EF electric service water heating system (i.e., a heat pump water heater), or ≥ 0.4 solar fraction solar water heating system.
4. More efficient duct thermal distribution system
   - Requires 100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless or hydronic systems, or 100% of ducts within conditioned space.
5. Improved air sealing and efficient ventilation option
   - Requires air leakage ≤ 3.0 ACH50, and an energy recovery ventilator (ERV) or heat recovery ventilation (HRV) with at least 75% sensible recovery efficiency.

Cost Implication of the Code Change

This code change will increase the cost of construction. Costs for each option, except the enhanced envelope option, were evaluated.

For the HVAC option, the gas home was upgraded from an 80 AFUE to a 95 AFUE furnace and to a 16 SEER air conditioner, with 13 SEER as a baseline for climate zones 5 to 7 and 14 SEER for climate zones 1 to 4 based on federal appliance standards. The electric home costs reflect an upgrade from an 8.2 HSPF / 14 SEER heat pump to a 10.0 HSPF / 18 SEER unit, which exceeds the 16 SEER requirement, but the cost data used did not have a 16 SEER unit that also met the 10.0 HSPF requirement.

HVAC equipment option for Gas House with baseline 13 SEER AC (CZ 5-7 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 kBtuh, AFUE 80%[70]	EA	$897.00		$897.00	$968.16	(1)	($968.16)
Gas Chimney Vent, 4" dia.[71]	LF	$7.57	$8.45	$16.02	$17.80	(25)	($444.94)
Gas Chimney Vent, 3" dia. (water heater)[72]	LF	$6.29	$8.00	$14.29	$15.90	25	$397.38

70 Source: https://hvacdirect.com/goodman-80-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800803bn.html
71 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F385
72 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381

Gas furnace, 80 kBtuh, AFUE 95%[73]	EA	$1,308.10		$1,308.10	$1,411.88	1	$1,411.88
Vent piping, PVC, 2" dia.[74]	LF	$1.65	$3.02	$4.67	$5.22	40	$208.63
2" concentric vent kit[75]	EA	$37.69		$37.69	$40.68	1	$40.68
Condenser, 3 ton, 13 SEER[76]	EA	$1,254.00		$1,254.00	$1,353.48	(1)	($1,353.48)
Condenser, 3 ton, 16 SEER[77]	EA	$1,557.00		$1,557.00	$1,680.52	1	$1,680.52
Total to Builder							$972.50
Total to Consumer							$1,142.64

HVAC equipment option for Gas House with baseline 14 SEER AC (CZ 2-4 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Total to Builder, from above							$972.50
Condenser, 3-ton, 14 SEER[78]	EA	$1404.00		$1,404.00	$1,515.38	(1)	($1,515.38)
Condenser, 3-ton, 13 SEER[79]	EA	$1254.00		$1,254.00	$1,353.48	1	$1,353.48
Total to Builder							$810.60
Total to Consumer							$952.41

HVAC equipment option for Electric House: 3 Ton 10 HSPF 18 SEER Heat Pump

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER[80]	EA	$2,769.00		$2,769.00	$2,988.67	(1)	($2,988.67)
Heat Pump, 10.0 HSPF/18 SEER[81]	EA	$4,793.00		$4,793.00	$5,173.24	1	$5,173.24
Total to Builder							$2,184.57
Total to Consumer							$2,566.77

For the water heater option, the gas home cost is estimated with an upgrade from a 40-gallon gas water heater to a tankless water heater that meets this option's performance requirement of a 0.82 EF. The electric home Is estimated with an upgrade from a 50-gallon electric water heater to a heat pump water heater. In this case the requirement is an EF of 2.0, but most heat pump water heaters significantly exceed this level of performance, so a UEF of 3.75 for the water heater is used to estimate costs. The cost of a thermostatic mixing valve was also Included which allows the heat pump water heater tank temperature to safely be set higher, essentially Increasing its capacity.

Water Heater option for Gas House: Direct Vent Water Heater

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
40 gal gas water heater, 0.58 UEF[82]	EA	$469.00	$165.00	$634.00	$694.11	(1)	($694.11)

73 Source: https://www.lowes.com/pd/MRCOOL-88000-Max-BTU-Input-Natural-gas-95-Percent-Upflow-Horizontal-Forced-Air-Furnace/1002553456

74 Source: https://www.menards.com/main/plumbing/pipe-fittings/pvc-pipe-fittings/pvc-sch-40-plain-end-solid-core-pipe/pvc07200060O/p-1444426391701-c-8571.htm?tid=-3946052023881235O6&ipos=3

75 Source: https://www.supplyhouse.com/Rheem-SP20897-2-PVC-Concentric-Vent-Termination-Kit

76 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html

77 Source: https://hvacdirect.com/goodman-3-ton-16-seer-air-conditioner-condenser-gsx160361.html

78 Source: https://hvacdirect.com/goodman-3-ton-14-seer-air-conditioner-condenser-gsx140361.html

79 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html

80 Source: https://hvacdirect.com/goodman-3-ton-14-seer-heat-pump-air-conditioner-system-id694.html

81 Source: https://hvacdirect.com/3-ton-18-seer-goodman-heat-pump-air-conditioner-system-id4356.html

82 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/sure-comfort-reg-40-gallon-3-year-34-000-btu-tank-natural-gas-water-heater/scg40t03st34u1/p-1512113333694-c-1541513694149.htm?tid=-6303961517209927637&ipos=4

Tankless gas water heater, 0.82 UEF[83]	EA	$749.00	$174.00	$923.00	$1,006.57	1	$1,006.57
Concentric vent wall termination kit[84]	EA	$68.34		$68.34	$73.76	1	$73.76
Concentric vent 39" extension[85]	EA	$38.03		$38.03	$41.05	1	$41.05
Gas Chimney Vent, 3" dia. (WH connector)[86]	LF	$6.29	$8.00	$14.29	$15.90	(4)	($63.58)
Gas piping, 1/2"[87]	LF	$1.81	$5.25	$7.06	$7.93	(10)	($79.34)
Gas piping, 1"[88]	LF	$2.64	$6.25	$8.89	$9.96	10	$99.62
15-amp circuit, toggle, 40' #14/2 NM[89]	EA	$15.97	$23.50	$39.47	$44.00	1	$44.00
GFCI 15-amp, 1-pole breaker[90]	EA	$36.37		$36.37	$39.26	1	$39.26
Total to Builder							$467.23
Total to Consumer							$548.97

Water Heater option for Electric House: 50 gal Heat Pump Water (HPWH)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
50 gal electric water heater[91]	EA	$499.00		$499.00	$538.59	(1)	($538.59)
HPWH, 50 gal, minimum 2.0 EF[92]	EA	$1,359.00		$1,359.00	$1,466.81	1	$1,466.81
Thermostatic Mixing Valve[93]	EA	$51.56	$16.50	$68.06	$74.44	1	$74.44
Total to Builder							$1,002.67
Total to Consumer							$1,178.09

For the ventilation option, costs were evaluated for the electric and gas house. In climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50, while the other climate zones were already at 3 ACH50. There was no cost assumed for this option for climate zone 7 because a cost for an ERV from RE139 already met the requirements for this option.

Ventilation Option Gas House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[94]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[95]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[96]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[97]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86

83 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/richmond-reg-mid-efficiency-7-gpm-160-000-btu-tankless-natural-gas-water-heater/rmtg70dvln-1/p-1523946516023-c-1545136941149.htm?tid=-8262144216229865118ipos=2
84 Source: https://www.supplyhouse.com/Noritz-PVC-2CT-2-PVC-Concentric-Horizontal-Termination?utm_source=bingad&utm_medium=shopping&msclkid=cfe17b3f3b2f169466d21a98cfa62d6e#product-overview
85 Source: https://www.supplyhouse.com/Rinnai-224053-39-Vent-Pipe-Extension-Non-Condensing
86 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381
87 Source: https://www.homedepot.com/p/HOME-FLEX-1-2-in-CSST-x-25-ft-Corrugated-Stainless-Steel-Tubing-11-00525/203073939
88 Source: https://www.homedepot.com/p/HOME-FLEX-1-in-CSST-x-150-ft-Corrugated-Stainless-Steel-Tubing-11-01050/204767409
89 Source: https://www.homedepot.com/p/Leviton-15-Amp-Single-Pole-Toggle-Switch-Ivory-R51-01451-0Il/100356974
90 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gfcicp/p-1444444038687-c-1489563170892.htm?tid=7536214849671723670&ipos=1
91 Source: https://www.homedepot.com/p/Rheem-Performance-50-Gal-Medium-6-Year-4500-4500-Watt-Elements-Electric-Tank-Water-Heater-XE50M06S145U1/205810732
92 Source: https://www.menards.com/main/plumbing/water-heaters/heat-pump-water-heaters/hybrid-water-heater/10e50-hp530/p-11050051203848487-c-8686.htm?tid=23404756352330936666&ipos=1
93 Source: https://www.lowes.com/pd/Cash-Acme-HG110-D-3-4-in-ID-FNPT-x-3-4-in-OD-FNPT-Brass-Thermostatic-Mixing-Valve/1003893690
94 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203256362
95 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
96 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258496
97 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate

Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[98]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[99]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[100]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[101]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[102]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

Ventilation Option Electric House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[103]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[104]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[105]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[106]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[107]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[108]	LF	$0.38	$1.37	$1.75	$1.97	2	$39.41
GFCI 15-amp 1-pole breaker[109]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[110]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[111]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

For the ventilation option in climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50. Decreasing infiltration generally includes additional labor time to complete air sealing details with materials on site. NREL's National Residential Efficiency Measure Database estimates that as a *retrofit* measure improving infiltration from 5 to 3 ACH 50 will cost between $0.22/SF and $0.82/SF, with an average of $0.52/SF. Note that these are costs for a retrofit, and air sealing new construction can be performed at a

98 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

99 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4

100 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

101 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935

102 Source: https://www.supplyhouse.com/Lambro-Industries-36IW-6-White-Plastic-Louvered-Wall-Vent

103 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362

104 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls

105 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495

106 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate

107 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

108 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4

109 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/homl15gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

110 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935

111 Source: https://www.supplyhouse.com/Lambro-Industries-36IW-6-White-Plastic-Louvered-Wall-Vent

substantially lower cost. NREL's BEopt 2.8.0.0 includes a cost for air sealing new construction, which shows an incremental cost of $0.105/SF for this level of improvement, which was ultimately used in this analysis.

Ventilation Option Electric House in CZ 2

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Associated ERV cost to builder from above							$1,452.58
Improve ACH50 from 5 to 3, estimate[112]	SF	$0	$0.105	$0.10	$0.12	2500	$298.14
Total to Builder							$1,750.72
Total to Consumer							$2,057.02

For the ventilation option, conditioned basements and conditioned crawlspaces were not evaluated, typically they would include the air handlers and ductwork, so there would be no incremental cost for homes with these foundations to meet this option. Slab homes were considered to meet the requirement by burying ducts per section R403.3.3, which required at least R-19 insulation above the duct, and R-13 insulation wrapped around the duct in climate zones 1 through 3. The air handler was located in a newly constructed mechanical closet to meet the requirements of R403.3.2.

Duct Option: Slab House, Buried Ducts, CZ 2-3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R13 duct: add FSK min R5 over R8 duct[113]	SF	$0.31	$1.70		$2.01	$2.15	680	$1,461.21
Add ceiling insulation, R19 blown[114]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[115]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[116]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[117]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[118]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$2,020.87
Total to Consumer								$2,374.43

112 Source: BEopt 2.8.0.0 https://www.nrel.gov/buildings/beopt.html
113 Source: https://www.plumbersstock.com/qflex-dw83048050-2in-48x50ft-r8-ductwrap.html
114 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1
115 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1011223/p-1444421962026-c-5656.htm?tid=-5114540465575422448&ipos=3
116 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363
117 Source: https://www.lowes.com/pd/23-32-Category-S7P-Rated/1003124592
118 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756

Duct Option: Slab House, Buried Ducts, CZ 4-7

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Add ceiling insulation, R19 blown[119]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[120]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[121]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[122]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[123]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$559.65
Total to Consumer								$657.57

For the ventilation option, crawl space homes were converted from a vented to an unvented crawlspace, which resulted in a decrease in construction costs.

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[124]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)
Wall insulation, foil-faced polyiso, 1", R6[125]	SF	$0.53	$0.37		$0.90	$0.93	1,000	$929.98
Foundation vents[126]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[127]	SF	$0.08	$0.08		$0.16	$0.17	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[128]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($688.27)
Total to Consumer								($808.69)

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 4

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[129]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)

119 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611840/p-1520336262471-c-5777.htm?tid=4399096187601806274&ipos=1

120 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1311223/p-1444421962026-c-5656.htm?tid=-5114540465754224488&ipos=3

121 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363

122 Source: https://www.lowes.com/pd/23-32-Category-SYP-Rated/1003124582

123 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756

124 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748

125 Source: https://www.lowes.com/pd/Common-1-in-x-4-ft-x-8-ft-Actual-0-9375-in-x-3-875-ft-x-7-875-ft-R-Expanded-Polystyrene-Foam-Board-Insulation/3365576

126 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074

127 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151

128 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E1541R-04X12/300713055?source=shoppingads&locale=en-US

129 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748

Wall insulation, foil-faced polyiso, 2", R12[130]	SF	$1.16	$0.40		$1.56	$1.59	1,000	$929.98
Foundation vents[131]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[132]	SF	$0.08	$0.08		$0.16	$0.16	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[133]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($30.89)
Total to Consumer								($36.30)

130 Source: https://www.lowes.com/pd/Johns-Manville-Common-2-in-x-4-ft-x-8-ft-Actual-2-in-x-4-ft-x-8-ft-AP-Foil-R-13-Faced-Polyisocyanurate-Foam-Board-Insulation/3351107
131 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074
132 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151
133 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E154R-04X12/300713055?source=shoppingads&locale=en-US

CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of Code Change:

This code change requires that for insulation materials without an observable R-value (e.g., blown-in insulation), that the R-value must be left after installation in a conspicuous location in the building.

Cost Implication of the Code Change

This code change will not change the cost of construction. Other code requirements in this same section already require the R-value to be known or displayed and this change mostly clarifies when that data must be communicated. Therefore, no cost impact is assumed for the reference home.

CE151.2

Reference Code Section

R202 Defined terms (new); R403.3.1 Ducts located outside conditioned space

Summary of Code Change:

This code change adds a definition for Thermal Distribution Efficiency (TDE) and requirements for ducts buried underneath buildings.

Cost Implication of the Code Change

This code change may decrease the cost of construction in limited cases, but it will not impact any homes in this analysis. Therefore, no cost impact is assumed for the reference home.

APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

Proposal	Description	Affected CZ	Reference House	CZ 2	
				Phoenix	
				Mass (30%)	Frame (70%)
				Electric	Electric
				Slab	Slab
				100%	100%
RE7	Lighting: revised definition of high-efficacy	All	$0		
RE18, RE20, RE21	Certificate: additional info	All	$0		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680		
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198		
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA		
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67		
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0		
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0		
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6
RE49	Baffles at attic access	All	$0		
RE72	Air seal narrow framing cavities	All	$0		

RE82	Air seal rim (basement; unvented crawlspace	All	$0		
RE82	Air seal rim (slab, vented crawlspace)	All	$0		
RE96	House tightness, allows trade-off for performance path	All	$0		
RE103	Air seal electrical & communication outlet boxes	All	$0		
RE106	Thermostat: requires 7-day programming	All	$0		
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0		
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742		
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33	$33
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		
RE148	Lighting, commercial	All	NA		
RE149	Lighting: exterior controls	All	$0		
RE151	Performance path backstop: 2009 IECC	All	NA		
RE178	Performance path ventilation type to match proposed	All	NA		
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0		
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA		
	Sub-total without additional efficiency package option			$297	$297
	Weighted average, foundations				$297

			Nat Ave	CZ 2
	Without additional efficiency package options		$1,373	$297
RE209	HVAC option		$1,900	$2,567
RE209	Water Heater option		$901	$1,178
RE209	Ventilation option		$1,788	$2,057

RE209	Duct option, slab house		$1,870	$2,374
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$2,864
	Total with Water Heater option		$2,274	$1,475
	Total with Ventilation option		$3,161	$2,354
	Total with Duct option, slab house		$3,243	$2,672
	Total with Duct option, vented crawlspace house			

Proposal	Description	Affected CZ	Reference House	CZ 3					
				Memphis					
				Mass (10%)			Frame (90%)		
				Electric			Electric		
				Slab	Base ment	Crawl	Slab	Base ment	Crawl
				75%	10%	15%	75%	10%	15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18, RE20, RE21	Certificate: additional info	All	$0						
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742						
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709	$709			$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709						
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226	$226	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198						
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						

RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67	$67	$67	$67	$67	$67	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0						
RE72	Air seal narrow framing cavities	All	$0						
RE82	Air seal rim (basement; unvented crawlspace	All	$0						
RE82	Air seal rim (slab, vented crawlspace)	All	$0						
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$0						
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47			$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0						
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33			$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42		$42	$42
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$0						

RE151	Performance path backstop: 2009 IECC	All	NA							
RE178	Performance path ventilation type to match proposed	All	NA							
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0							
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA							
	Sub-total without additional efficiency package option			$1,073	$419	$372	$1,073	$419	$372
	Weighted average, foundations					$1,347			$1,347
			Nat Ave	CZ 3					
	Without additional efficiency package options		$1,373	$902					
RE209	HVAC option		$1,900	$2,567					
RE209	Water Heater option		$901	$1,178					
RE209	Ventilation option		$1,788	$1,707					
RE209	Duct option, slab house		$1,870	$2,545					
RE209	Duct option, vented crawlspace house			($1,339)					
	Total with HVAC option		$3,273	$3,469					
	Total with Water Heater option		$2,274	$2,080					
	Total with Ventilation option		$3,161	$2,609					
	Total with Duct option, slab house		$3,243	$3,447					
	Total with Duct option, vented crawlspace house			($437)					

Proposal	Description	Affected CZ	Reference House	CZ 4		
				Baltimore		
				Frame Wall		
				Gas		
				Slab	Basement	Crawl
				20%	60%	20%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742	$1,742	$1,742	$1,742
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67	$67	$67	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,786	$2,133	$2,086
	Weighted average, foundations					$2,254
			Nat Ave	CZ 4		
	Without additional efficiency package options		$1,373	$2,254		
RE209	HVAC option		$1,900	$952		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$1,190		

RE209	Duct option, vented crawlspace house			($205)
	Total with HVAC option		$3,273	$3,206
	Total with Water Heater option		$2,274	$2,803
	Total with Ventilation option		$3,161	$3,961
	Total with Duct option, slab house		$3,243	$3,444
	Total with Duct option, vented crawlspace house			$2,049

Proposal	Description	Affected CZ	Reference House	CZ 5 Chicago Frame Wall Gas		
				Slab 15%	Basement 70%	Crawl 15%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680	$2,680	$2,680	$2,680
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			

RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			

	Sub-total without additional efficiency package option			$3,658	$3,004	$3,004
	Weighted average, foundations					$3,102
			Nat Ave	CZ 5		
	Without additional efficiency package options		$1,373	$3,102		
RE209	HVAC option		$1,900	$1,143		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$1,213		
RE209	Duct option, vented crawlspace house					
	Total with HVAC option		$3,273	$4,245		
	Total with Water Heater option		$2,274	$3,651		
	Total with Ventilation option		$3,161	$4,809		
	Total with Duct option, slab house		$3,243	$4,315		
	Total with Duct option, vented crawlspace house					

Proposal	Description	Affected CZ	Reference House	CZ 6		
				Helena		
				Frame Wall		
				Gas		
				Slab	Basement	Crawl
				5%	90%	5%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$269	$324	$324
	Weighted average, foundations					$321

		Nat Ave	CZ 6
	Without additional efficiency package options	$1,373	$321
RE209	HVAC option	$1,900	$1,143
RE209	Water Heater option	$901	$549
RE209	Ventilation option	$1,788	$1,707
RE209	Duct option, slab house	$1,870	$605

RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$1,464
	Total with Water Heater option		$2,274	$870
	Total with Ventilation option		$3,161	$2,028
	Total with Duct option, slab house		$3,243	$926
	Total with Duct option, vented crawlspace house			

Proposal	Description	Affected CZ	Reference House	CZ 7 Duluth Frame Wall Gas		
				Slab 30%	Basement 5%	Crawl 65%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			

RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742	$1,742	$1,742	$1,742
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,011	$2,066	$2,066

	Weighted average, foundations			$2,050
			Nat Ave	CZ 7
	Without additional efficiency package options		$1,373	$2,050
RE209	HVAC option		$1,900	$1,143
RE209	Water Heater option		$901	$549
RE209	Ventilation option		$1,788	$0
RE209	Duct option, slab house		$1,870	$619
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$3,192
	Total with Water Heater option		$2,274	$2,599
	Total with Ventilation option		$3,161	$2,050
	Total with Duct option, slab house		$3,243	$2,669
	Total with Duct option, vented crawlspace house			

APPENDIX C: LOCATION ADJUSTMENT FACTORS

State	City	Cost Adjustment Factor	State	City	Cost Adjustment Factor
Alabama	Birmingham	0.84	Montana	Billings	0.89
Alabama	Mobile	0.83	Nebraska	Omaha	0.90
Alaska	Fairbanks	1.21	Nevada	Las Vegas	1.03
Arizona	Phoenix	0.84	New Hampshire	Portsmouth	0.95
Arizona	Tucson	0.84	New Jersey	Jersey City	1.18
Arkansas	Little Rock	0.83	New Mexico	Albuquerque	0.86
California	Alhambra	1.15	New York	Long Island City	1.36
California	Los Angeles	1.15	New York	Syracuse	0.99
California	Riverside	1.13	North Carolina	Charlotte	0.99
California	Stockton	1.20	North Carolina	Hickory	0.93
Colorado	Boulder	0.90	North Carolina	Raleigh	0.94
Colorado	Colorado Springs	0.87	North Dakota	Fargo	0.87
Colorado	Denver	0.91	Ohio	Columbus	0.91
Connecticut	New Haven	1.10	Oklahoma	Oklahoma City	0.84
Delaware	Dover	1.02	Oklahoma	Tulsa	0.83
District of Columbia	Washington, D.C.	0.92	Oregon	Bend	1.02
Florida	Fort Meyers	0.79	Pennsylvania	Norristown	1.05
Florida	Miami	0.83	Pennsylvania	State College	0.94
Florida	Orlando	0.82	Rhode Island	Providence	1.09
Florida	Tampa	0.81	South Carolina	Greenville	0.97
Georgia	Atlanta	0.90	South Dakota	Sioux Falls	0.92
Hawaii	Honolulu	1.22	Tennessee	Memphis	0.87
Idaho	Boise	0.89	Texas	Austin	0.80
Illinois	Chicago	1.25	Texas	Dallas	0.84
Indiana	Indianapolis	0.92	Texas	Houston	0.84
Iowa	Des Moines	0.92	Texas	San Antonio	0.83
Kansas	Wichita	0.81	Utah	Ogden	0.84
Kentucky	Louisville	0.89	Utah	Provo	0.85
Louisiana	Baton Rouge	0.85	Utah	Salt Lake City	0.85
Maine	Portland	0.94	Vermont	Burlington	0.95
Maryland	Baltimore	0.93	Virginia	Fairfax	1.00
Massachusetts	Boston	1.18	Virginia	Winchester	0.99
Michigan	Ann Arbor	0.99	Washington	Tacoma	1.05
Minnesota	Minneapolis	1.09	West Virginia	Charleston	0.94
Mississippi	Biloxi	0.83	Wisconsin	La Crosse	0.95
Missouri	Springfield	0.86	Wyoming	Casper	0.85

APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation minimum R-values and fenestration requirements for the 2021 IECC, with redline text indicating changes from the 2018 IECC.

Insulation Minimum R-value and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC

Climate Zone	Fenestration U-factor	Skylight U-factor	Fenestration SHGC	Ceiling R-value	Frame Wall R-value	Mass Wall R-value	Floor R-value	Basement wall R-value*	Slab R-value & depth	Crawl Space wall R-value*
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	~~38~~ 49	13	4/6	13	0	0	0
3	~~0.32~~ 0.30	0.55	0.25	~~38~~ 49	20	8/13	19	5/13	~~0~~ 10, 2 ft	5/13
4 except Marine	~~0.32~~ 0.30	0.55	0.40	~~49~~ 60	~~20~~ 20+5	8/13	19	10/13	~~10, 2 ft~~ 10, 4 ft	10/13
5 and Marine 4	0.30	0.55	~~NR~~ 0.40	~~49~~ 60	~~20~~ 20+5	13/17	30	15/19	~~10, 2 ft~~ 10, 4 ft	15/19
6	0.30	0.55	NR	~~49~~ 60	20+5	15/20	30	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	~~49~~ 60	20+5	19/21	38	15/19	10, 4 ft	15/19

* Cavity insulation / continuous insulation

APPENDIX E: ENERGY USE BY CLIMATE ZONE

CZ	Fuel	Foundations	Wall	Code	Efficiency Option	kWh/yr	thrm/yr	$/yr
2	Electric	Slab	Mass	2018	Base	17,107	0	$2,225.62
2	Electric	Slab	Frame	2018	Base	17,087	0	$2,223.02
2	Electric	Slab	Mass	2018	2021 ceiling insulation	17,052	0	$2,218.47
2	Electric	Slab	Frame	2018	2021 ceiling insulation	17,028	0	$2,215.34
2	Electric	Slab	Mass	2021	Base	16,638	0	$2,164.60
2	Electric	Slab	Frame	2021	Base	16,615	0	$2,161.61
2	Electric	Slab	Mass	2021	HVAC option	15,727	0	$2,046.08
2	Electric	Slab	Frame	2021	HVAC option	15,715	0	$2,044.52
2	Electric	Slab	Mass	2021	Water Heater option	15,618	0	$2,031.90
2	Electric	Slab	Frame	2021	Water Heater option	15,589	0	$2,028.13
2	Electric	Slab	Mass	2021	Ventilation option	16,506	0	$2,147.43
2	Electric	Slab	Frame	2021	Ventilation option	16,465	0	$2,142.10
2	Electric	Slab	Mass	2021	Duct option	15,768	0	$2,051.42
2	Electric	Slab	Frame	2021	Duct option	15,715	0	$2,044.52
3	Electric	Slab	Mass	2018	Base	15,618	0	$2,031.90
3	Electric	Slab	Frame	2018	Base	15,557	0	$2,023.97
3	Electric	Cond Basement	Mass	2018	Base	16,612	0	$2,161.22
3	Electric	Cond Basement	Frame	2018	Base	16,547	0	$2,152.76
3	Electric	Vented Crawl	Mass	2018	Base	15,144	0	$1,970.23
3	Electric	Vented Crawl	Frame	2018	Base	15,056	0	$1,958.79
3	Electric	Slab	Mass	2018	2021 ceiling insulation	15,536	0	$2,021.23
3	Electric	Slab	Frame	2018	2021 ceiling insulation	15,472	0	$2,012.91

3	Electric	Cond Basement	Mass	2018	2021 ceiling insulation	16,521	0	$2,149.38
3	Electric	Cond Basement	Frame	2018	2021 ceiling insulation	16,451	0	$2,140.28
3	Electric	Vented Crawl	Mass	2018	2021 ceiling insulation	15,053	0	$1,958.40
3	Electric	Vented Crawl	Frame	2018	2021 ceiling insulation	14,959	0	$1,946.17
3	Electric	Slab	Mass	2018	2021 slab insulation	14,938	0	$1,943.43
3	Electric	Slab	Frame	2018	2021 slab insulation	14,877	0	$1,935.50
3	Electric	Slab	Mass	2018	2021 window U-Factor	15,566	0	$2,025.14
3	Electric	Slab	Frame	2018	2021 window U-Factor	15,501	0	$2,016.68
3	Electric	Cond Basement	Mass	2018	2021 window U-Factor	16,553	0	$2,153.55
3	Electric	Cond Basement	Frame	2018	2021 window U-Factor	16,489	0	$2,145.22
3	Electric	Vented Crawl	Mass	2018	2021 window U-Factor	15,091	0	$1,963.34
3	Electric	Vented Crawl	Frame	2018	2021 window U-Factor	14,994	0	$1,950.72
3	Electric	Slab	Mass	2021	Base	14,408	0	$1,874.48
3	Electric	Slab	Frame	2021	Base	14,344	0	$1,866.15
3	Electric	Cond Basement	Mass	2021	Base	15,903	0	$2,068.98
3	Electric	Cond Basement	Frame	2021	Base	15,832	0	$2,059.74
3	Electric	Vented Crawl	Mass	2021	Base	14,610	0	$1,900.76
3	Electric	Vented Crawl	Frame	2021	Base	14,519	0	$1,888.92
3	Electric	Slab	Mass	2021	HVAC option	13,485	0	$1,754.40
3	Electric	Slab	Frame	2021	HVAC option	13,450	0	$1,749.85
3	Electric	Cond Basement	Mass	2021	HVAC option	14,824	0	$1,928.60
3	Electric	Cond Basement	Frame	2021	HVAC option	14,786	0	$1,923.66
3	Electric	Vented Crawl	Mass	2021	HVAC option	13,561	0	$1,764.29
3	Electric	Vented Crawl	Frame	2021	HVAC option	13,502	0	$1,756.61

3	Electric	Slab	Mass	2021	Water Heater option	13,277	0	$1,727.34
3	Electric	Slab	Frame	2021	Water Heater option	13,212	0	$1,718.88
3	Electric	Cond Basement	Mass	2021	Water Heater option	14,742	0	$1,917.93
3	Electric	Cond Basement	Frame	2021	Water Heater option	14,669	0	$1,908.44
3	Electric	Vented Crawl	Mass	2021	Water Heater option	13,470	0	$1,752.45
3	Electric	Vented Crawl	Frame	2021	Water Heater option	13,382	0	$1,741.00
3	Electric	Slab	Mass	2021	Ventilation option	14,326	0	$1,863.81
3	Electric	Slab	Frame	2021	Ventilation option	14,259	0	$1,855.10
3	Electric	Cond Basement	Mass	2021	Ventilation option	15,727	0	$2,046.08
3	Electric	Cond Basement	Frame	2021	Ventilation option	15,651	0	$2,036.20
3	Electric	Vented Crawl	Mass	2021	Ventilation option	14,446	0	$1,879.42
3	Electric	Vented Crawl	Frame	2021	Ventilation option	14,346	0	$1,866.41
3	Electric	Slab	Mass	2021	Duct option	13,816	0	$1,797.46
3	Electric	Slab	Frame	2021	Duct option	13,749	0	$1,788.74
3	Electric	Vented Crawl	Mass	2021	Duct option	14,273	0	$1,856.92
3	Electric	Vented Crawl	Frame	2021	Duct option	14,174	0	$1,844.04
4	Gas	Slab	Frame	2018	Base	8,262	697	$1,807.43
4	Gas	Cond Basement	Frame	2018	Base	9,848	696	$2,012.72
4	Gas	Vented Crawl	Frame	2018	Base	8,669	665	$1,826.75
4	Gas	Slab	Frame	2018	2021 ceiling insulation	8,244	690	$1,797.73
4	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,833	689	$2,003.41
4	Gas	Vented Crawl	Frame	2018	2021 ceiling insulation	8,652	659	$1,818.23
4	Gas	Slab	Frame	2018	2021 slab insulation	8,180	674	$1,772.59
4	Gas	Slab	Frame	2018	2021 wall cont. insulation	8,177	661	$1,758.54

4	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,763	660	$1,963.83
4	Gas	Vented Crawl	Frame	2018	2021 wall cont. insulation	8,590	629	$1,778.64
4	Gas	Slab	Frame	2018	2021 window U-Factor	8,256	687	$1,796.14
4	Gas	Cond Basement	Frame	2018	2021 window U-Factor	9,848	686	$2,002.21
4	Gas	Vented Crawl	Frame	2018	2021 window U-Factor	8,666	656	$1,816.90
4	Gas	Slab	Frame	2021	Base	7,673	626	$1,656.18
4	Gas	Cond Basement	Frame	2021	Base	9,159	649	$1,873.68
4	Gas	Vented Crawl	Frame	2021	Base	8,174	616	$1,710.85
4	Gas	Slab	Frame	2021	HVAC option	7,348	565	$1,549.79
4	Gas	Cond Basement	Frame	2021	HVAC option	8,795	580	$1,753.81
4	Gas	Vented Crawl	Frame	2021	HVAC option	7,761	552	$1,589.86
4	Gas	Slab	Frame	2021	Water Heater option	7,629	601	$1,624.00
4	Gas	Cond Basement	Frame	2021	Water Heater option	9,144	614	$1,835.00
4	Gas	Vented Crawl	Frame	2021	Water Heater option	8,126	591	$1,678.00
4	Gas	Slab	Frame	2021	Ventilation option	7,931	586	$1,647.71
4	Gas	Cond Basement	Frame	2021	Ventilation option	9,481	584	$1,847.26
4	Gas	Vented Crawl	Frame	2021	Ventilation option	8,420	575	$1,699.77
4	Gas	Slab	Frame	2021	Duct option	7,495	581	$1,585.73
4	Gas	Vented Crawl	Frame	2021	Duct option	7,732	607	$1,643.89
5	Gas	Slab	Frame	2018	Base	7,666	1,102	$2,156.00
5	Gas	Cond Basement	Frame	2018	Base	9,297	1,089	$2,354.08
5	Gas	Cond Crawl	Frame	2018	Base	7,720	999	$2,054.32
5	Gas	Slab	Frame	2018	2021 ceiling insulation	7,691	1,090	$2,146.19
5	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,285	1,080	$2,343.06

5	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,702	991	$2,043.57
5	Gas	Slab	Frame	2018	2021 slab insulation	7,647	1,071	$2,120.50
5	Gas	Slab	Frame	2018	2021 wall cont. insulation	7,617	1,049	$2,093.47
5	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,209	1,040	$2,291.13
5	Gas	Cond Crawl	Frame	2018	2021 wall cont. insulation	7,635	952	$1,993.87
5	Gas	Slab	Frame	2021	Base	7,142	1,018	$1,999.09
5	Gas	Cond Basement	Frame	2021	Base	8,614	1,037	$2,210.57
5	Gas	Cond Crawl	Frame	2021	Base	7,216	947	$1,934.10
5	Gas	Slab	Frame	2021	HVAC option	6,770	898	$1,824.58
5	Gas	Cond Basement	Frame	2021	HVAC option	8,209	914	$2,028.60
5	Gas	Cond Crawl	Frame	2021	HVAC option	6,838	837	$1,769.31
5	Gas	Slab	Frame	2021	Water Heater option	7,137	998	$1,977.00
5	Gas	Cond Basement	Frame	2021	Water Heater option	8,618	1,003	$2,175.00
5	Gas	Cond Crawl	Frame	2021	Water Heater option	7,211	925	$1,910.00
5	Gas	Slab	Frame	2021	Ventilation option	7,400	966	$1,978.01
5	Gas	Cond Basement	Frame	2021	Ventilation option	8,927	960	$2,170.36
5	Gas	Cond Crawl	Frame	2021	Ventilation option	7,482	901	$1,920.36
5	Gas	Slab	Frame	2021	Duct option	7,022	929	$1,889.94
6	Gas	Slab	Frame	2018	Base	7,374	1,201	$2,221.61
6	Gas	Cond Basement	Frame	2018	Base	8,962	1,166	$2,391.42
6	Gas	Cond Crawl	Frame	2018	Base	7,345	1,057	$2,066.49
6	Gas	Slab	Frame	2018	2021 ceiling insulation	7,359	1,192	$2,210.20
6	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,945	1,155	$2,377.65
6	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,333	1,047	$2,054.42

6	Gas	Slab	Frame	2021	Base	6,970	1,198	$2,165.90
6	Gas	Cond Basement	Frame	2021	Base	8,379	1,162	$2,311.37
6	Gas	Cond Crawl	Frame	2021	Base	6,937	1,052	$2,008.16
6	Gas	Slab	Frame	2021	HVAC option	6,586	1,054	$1,964.59
6	Gas	Cond Basement	Frame	2021	HVAC option	7,984	1,024	$2,114.94
6	Gas	Cond Crawl	Frame	2021	HVAC option	6,583	930	$1,833.88
6	Gas	Slab	Frame	2021	Water Heater option	7,007	1,183	$2,155.00
6	Gas	Cond Basement	Frame	2021	Water Heater option	8,408	1,131	$2,282.00
6	Gas	Cond Crawl	Frame	2021	Water Heater option	6,973	1,033	$1,993.00
6	Gas	Slab	Frame	2021	Ventilation option	7,198	1,126	$2,119.89
6	Gas	Cond Basement	Frame	2021	Ventilation option	8,672	1,068	$2,250.70
6	Gas	Cond Crawl	Frame	2021	Ventilation option	7,189	995	$1,981.03
6	Gas	Slab	Frame	2021	Duct option	6,832	1,043	$1,985.04
7	Gas	Slab	Frame	2018	Base	7,284	1,701	**$2,735.00**
7	Gas	Cond Basement	Frame	2018	Base	8,822	1,641	$2,873.00
7	Gas	Cond Crawl	Frame	2018	Base	7,236	1,497	$2,515.00
7	Gas	Slab	Frame	2018	2021 ceiling insulation	7,239	1,694	$2,722.00
7	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,807	1,628	$2,857.00
7	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,221	1,484	$2,499.00
7	Gas	Slab	Frame	2021	Base	7,321	1,605	$2,639.32
7	Gas	Cond Basement	Frame	2021	Base	8,787	1,523	$2,743.86
7	Gas	Cond Crawl	Frame	2021	Base	7,283	1,419	$2,438.89
7	Gas	Slab	Frame	2021	HVAC option	6,879	1,403	$2,369.51
7	Gas	Cond Basement	Frame	2021	HVAC option	8,344	1,333	$2,486.54

7	Gas	Cond Crawl	Frame	2021	HVAC option	6,870	1,244	$2,201.23
7	Gas	Slab	Frame	2021	Water Heater option	7,374	1,594	$2,635.00
7	Gas	Cond Basement	Frame	2021	Water Heater option	8,824	1,494	$2,718.00
7	Gas	Cond Crawl	Frame	2021	Water Heater option	7,327	1,404	$2,429.00
7	Gas	Slab	Frame	2021	Ventilation option	7,307	1,588	$2,619.63
7	Gas	Cond Basement	Frame	2021	Ventilation option	8,772	1,502	$2,719.84
7	Gas	Cond Crawl	Frame	2021	Ventilation option	7,271	1,403	$2,420.51
7	Gas	Slab	Frame	2021	Duct option	7,210	1,409	$2,418.88
7	Gas	Slab	Frame	2021	No HRV	7,087	1,671	$2,678.24
7	Gas	Cond Basement	Frame	2021	No HRV	8,479	1,607	$2,792.07
7	Gas	Cond Crawl	Frame	2021	No HRV	7,028	1,466	$2,455.11

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Home Innovation Response to ICF Comments Regarding 2021 IECC Residential Cost Effectiveness Analysis

This is a response by Home Innovation Research Labs to an ICF report that contradicted the analysis in Home Innovation's *2021 IECC Residential Cost Effectiveness Analysis*.[1] Home Innovation stands by our analysis as comprehensive and accurate.

The 2021 IECC includes several changes that impact both energy savings and construction costs for residential construction. The objective of the Home Innovation analysis was to quantify the incremental construction cost and energy use cost savings associated with constructing a house compliant with the 2021 IECC, relative to a 2018 IECC baseline, and to evaluate the cost-effectiveness of the code changes.

In response, ICF prepared a report and accompanying comparison document with concerns and issues. Per ICF, "This analysis is intended to 'check the math' of the NAHB report using current cost data and widely accepted cost effectiveness metrics." Throughout their report, ICF makes comparisons to a 2021 IECC analysis by Pacific Northwest National Laboratory (PNNL).[2]

Home Innovation reviewed the ICF report and accompanying comparison document. The different results between the Home Innovation and ICF reports are primarily due to different incremental construction costs, and the decision around which of these costs should be included to evaluate cost-effectiveness. To calculate cost-effectiveness, ICF used Home Innovation's energy use costs, but developed their own construction costs. ICF used bare material costs that are generally much lower than Home Innovation's and, in some cases, eliminated costs altogether. ICF used the same base labor costs as Home Innovation, but did not accurately account for subcontractor overhead. Finally, ICF did not properly apply builder gross margin to total subcontractor costs. As a result, ICF underestimated the total construction costs to consumer. Home Innovation stands by our construction costs as comprehensive, robust, and accurate.

ICF's issues with Home Innovation's report fall within three broad categories: **(1)** Metric used to evaluate cost-effectiveness; **(2)** Methodology and construction data (e.g., housing starts, foundation type) used for the analysis; and **(3)** Construction costs. Our response to the issues raised by ICF in these categories is provided below.

(1) Metric used to evaluate cost-effectiveness

- ICF criticized Home Innovation for using only the Simple Payback metric to evaluate cost-effectiveness. Home Innovation uses Simple Payback because that is what builders use. Life Cycle Cost (LCC), Simple Payback, and Net Present Value/Cash Flow methods can all be used to calculate cost-effectiveness, but real-world builders do not use LCC to make design and construction decisions because the housing finance system does not support that methodology. ICF used LCC and Simple Payback; PNNL used all three. The value of any metric depends mostly on accurate construction costing and energy modeling. The metrics are inter-related – results from one metric will generally not be improved simply by selecting another.

[1] Home Innovation 2021 IECC analysis: https://www.homeinnovation.com/trends_and_reports/featured_reports/2021_iecc_residential_cost_effectiveness_analysis

[2] PNNL analysis: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf

(2) Methodology and construction data used for the analysis

- ICF criticized Home Innovation's methodology and source of data, the Builder Practices Survey (BPS), used to determine weighted national average results and reference new home characteristics compared to Census data used by DOE/PNNL. Reported data on home starts and characteristics are actually very similar between these two sources – and ultimately, so are the results for energy savings. BPS data rely on an annual survey with about 1,500 home builders participating each year, reporting on the characteristics of the 40,000+ homes they constructed. There are some differences in reporting conventions between the two sources that can account for the minor variations between BPS and Census data. For example, the BPS reports single-family detached housing starts and characteristics, while Census single-family housing includes detached and attached units. The table below shows housing starts distribution across Climate Zones used in the PNNL and Home Innovation analyses.

Construction Data Comparison: Housing Starts

	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Home Innovation	28%	28%	21%	17%	5%	1%
PNNL, adjusted by combining CZ1&2 and CZ7&8	*26.73%*	*29.04%*	*19.49%*	*19.51%*	*4.68%*	*0.55%*

  There were some differences in the construction data used for analysis – Home Innovation evaluated single-family detached housing only, while PNNL evaluated single-family and low-rise multifamily buildings. For primary heating fuel, Home Innovation evaluated natural gas or electric, depending on the predominant fuel by location; PNNL evaluated natural gas, electric, and fuel oil (however, fuel oil represents a relatively small 3.8% of housing starts and therefore does not have a significant impact on the weighted results). Despite these differences, and the different data sources and geographic locations selected for energy modeling, the results for national average energy cost savings are similar: 8.66% for PNNL; 9.7% for Home Innovation. ICF acknowledged the results are comparable, but pointed to two outliers where the results were farther apart (Climate Zones 3 and 7). Home Innovation discussed those in 2021 with PNNL and determined the differences do not significantly affect our national average results. Regardless, even though ICF disputes the validity of Home Innovation's energy results, they still *used* Home Innovation's energy results (i.e., our methodology and weighting) in their analysis.

- ICF criticized Home Innovation for including the costs of code changes in the cost-effectiveness analysis when these code changes were not included in the energy modeling analysis. However, these costs are real and must be included to accurately account for the cost of compliance associated with the 2021 IECC. This is an important distinction that can significantly affect any cost-effectiveness analysis. For this study it is likely the second most important difference, after construction costs, between the different results. We included all construction costs in our analysis because all the code changes are required for compliance with the 2021 IECC (as applicable, meaning not all changes are applicable in all Climate Zones), and it was necessary in order to evaluate the overall cost-effectiveness of the 2021 IECC relative to the 2018 IECC. Where we investigated the cost-effectiveness of individual code changes (e.g., ceiling insulation, wall insulation, slab insulation, window U-factor, additional efficiency package options), we only used the construction cost associated with the individual change, so this issue did not impact those results.

  We determined construction costs for a total of 20 code changes. Ten of those code changes have a direct impact on energy efficiency and can be reasonably quantified through energy modeling – e.g., more ceiling insulation, more efficient windows, etc. PNNL and Home Innovation selected the same 10 code changes for energy modeling. The other code changes that were not included in the energy modeling are changes with either no energy savings (i.e., administrative, such as a providing a certificate) or energy savings that can't reasonably be accounted for (e.g., insulation baffles at the attic access hatch; air-sealed electrical outlet boxes; exterior lighting controls). Some of these changes represent minor costs while others are more significant, but all are *real costs* and should be included in the analysis to accurately account for the total construction cost of compliance associated with the 2021 IECC changes.

- ICF wrongly stated that Home Innovation made a misleading comparison of cost effectiveness by comparing the 2021 efficiency package options to a 2021 baseline in Table 21, and that we should have compared those to a 2018 baseline. Table 11 in our report shows exactly what ICF is recommending – we compare the 2021 with and without package options to the 2018 baseline. Table 21 was included specifically to evaluate individual code changes. Further, we evaluated four of the five 2021 IECC additional efficiency package options; PNNL limited their investigation to one (water heating).

Table 11. Simple Payback relative to 2018 Baseline Reference House, years

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	48	43	31	62	61	47	78
2021 with HVAC option	38	47	39	39	32	19	24
2021 with Water Heater option	32	20	20	54	54	42	79
2021 with Ventilation option	67	90	49	75	68	50	63
2021 with Duct option, slab house	38	38	36	46	39	23	26
2021 with Duct option, vented crawlspace house			30	46			

(3) Construction Costs

- ICF used lower material costs and, in some cases, eliminated costs that we believe are required. Home Innovation stands by our costs as robust, comprehensive, and accurate, understanding that builders may adjust the final costs as they see fit. We build *real* prices, for *real* builders. We conduct many cost studies, and our results are commonly vetted by both large- and small-volume builders and their purchasing staff. We developed our estimated costs based on current 2021 RSMeans Residential Data, the most recognized industry standard for costing, using national average costs for labor and construction materials; mechanical equipment costs were sourced from national distributor websites. We show our assumptions and individual component costs in Appendix A of our reports, so we are very transparent. Home Innovation also relies on internet pricing, as needed, but, without due diligence and construction experience, price information found on the internet may not consistently capture accurate costs. An internet price, for example, may represent a sale price that is only available for a limited time or not available nationwide. Likewise, internet pricing information may not be complete – e.g., a linear foot price for piping may not include fittings and hangers; a shingle price may not include delivery onto the roof or account for normal waste; blown ceiling insulation sold by the bag requires a cost calculation to convert cubic feet to square foot of ceiling for a given R-value; and so on. RSMeans incorporates this type of comprehensive calculation, which minimizes the potential for errors; an estimate that does not use RSMeans must be transparent about the calculation.

- ICF applies the builder gross margin as if it were a mark-up – this is an error and underestimates the final cost to consumers. ICF provides an example for a $200 cost to builder with $247 cost to consumer and states that this represents a 24% gross margin, but that calculation is incorrect. This example actually represents a 19.0% gross margin ($47/$247) and an approximate 24% mark-up ($47/$200). This is not trivial. For a contractor, misunderstanding this concept can be the difference between being a viable business and going out of business.

- Home Innovation applied a builder gross margin of 19% (not 24% as ICF claimed). ICF used a gross margin of 17.5% (applied as a mark-up) based on a 15-year average (no source provided for this data), which further underestimates the current cost to consumers. Home Innovation used the most recent data available: 19% was the industry average gross profit margin for 2017 as reported by the NAHB 2019 Builder's Cost of Doing Business Study.[3] Since then, a 2020 NAHB study reports an average 20.4% builder gross margin for 2019.[4]

- ICF stated, "the excessively high profit margin of 24% was applied twice, once reflecting the subcontractor's profit and again to reflect the builder's profit." ICF is not correct in this depiction. Home Innovation assumed that all construction was conducted by subcontractors and applied a gross margin of 19% (not 24%) only once. ICF conflates builder gross margin and subcontractor overhead – those are separate and distinct items and, again, not a trivial matter to misinterpret them.

- ICF improperly accounts for subcontractor's overhead for labor – where labor is a factor, the real cost to builders and consumers will be higher. ICF marked-up materials and labor by about 10% but did not apply an overhead burden to labor first. RSMeans provides the "Total Cost Including Overhead and Profit" for the installing contractor (designated by RSMeans as "Total Incl O&P" and designated by Home Innovation in our tables as "w/O&P"). This represents the total cost charged by the subcontractor to the builder. Note that this figure is normally not calculated by the estimator. Per RSMeans, this figure is the sum of the bare material cost plus 10% for profit, the bare equipment cost plus 10% for profit, and the base labor cost plus overhead and 10% for profit. The base labor cost includes fringe benefits, such as vacation pay and employer-paid healthcare. Overhead includes direct overhead, such as workers' compensation insurance, federal and state unemployment costs, and social security taxes, and fixed overhead (RSMeans uses 18.5% for 2021). RSMeans determines the national average cost for overhead and applies this as a mark-up to the base labor cost. This mark-up varies by trade, but the average for skilled workers (comprising 35 trades) is 54.5% (i.e., multiply the base labor cost by 1.545), before the 10% profit for the subcontractor. These figures represent national averages as reported by RSMeans 2021 Residential Cost Data. Note that RSMeans does not include costs for general conditions, contingencies, or sales tax on materials.

- ICF applied a factor of 79.3% to subcontractor mark-ups to reflect the average share of construction costs that are subcontracted. We consider this arbitrary and inconsistent with RSMeans. There is always overhead

[3] **NAHB 2019 Study:** https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

[4] **NAHB 2020 Study:** https://eyeonhousing.org/2020/02/cost-of-constructing-a-home-in-2019/

associated with labor and construction, and builder gross margin does not include overhead associated with total construction cost. Large builders typically subcontract all construction. Where builders have an in-house crew or division, these typically operate as an independent profit center and likely would charge the same as a subcontractor – they will still have direct labor overhead and overhead associated with construction. Further, smaller builders that likely subcontract less (e.g., do their own carpentry), generally have larger overhead as a percentage of sales (per RSMeans).

- ICF incorrectly states that, for 19 of the 153 houses modeled, Home Innovation reported "a significant error where the reported energy use and energy rates did not result in the documented energy costs." However, the energy costs that we reported were calculated by the energy modeling software BEopt hourly simulation software, developed by DOE. Calculating the results manually, as ICF apparently did, is more likely to introduce errors.

- ICF took issue with our costing of a few minor items (e.g., $114 administrative costs). A builder may choose to reduce or eliminate our estimated costs for these code changes, but doing so does not affect our analysis or results in any meaningful way.

CONCLUSION

Home Innovation stands by our results. We build *real* prices, for *real* builders. We base our estimated costs on current RSMeans Residential Data (2021 data for this report), using national average costs for labor and construction materials, and mechanical equipment costs sourced from distributor websites. We show our assumptions and individual component costs in Appendix A of our reports, so our analysis is transparent. Our cost studies and results are commonly vetted by builders, large and small, and their professional purchasing staffers. If a builder believes any assumptions we make or costs are wrong, rest assured, we hear about it. Anecdotally, we recently presented a similar study, and the feedback from major national builders was, "I don't think we could do it for that," meaning our estimates were conservative and might even be low. In another recent study, we evaluated the installed costs of wall cavity insulation and ceiling insulation and found that current RSMeans costs correlate well with market internet pricing. Actual costs will vary by builder and location, but our costs are likely low for many smaller builders with less purchasing power, and may even be low now for larger builders due to current market conditions. Also, note that our cost analysis does not account for the inflation that is throughout the economy and widespread within the building industry.

NAHB Priced-Out Estimates for 2022

February 2022
Special Study for Housing Economics
Na Zhao, Ph.D.
Economics and Housing Policy
National Association of Home Builders

This article presents the NAHB's "priced out estimates" for 2022, showing how higher prices and interest rates affect housing affordability. The 2022 US estimates indicate that a $1,000 increase in the median new home price ($412,505[1]) would price 117,932 households out of the market. As a benchmark, 87.5 million households (roughly 69 percent of all U.S. households) are not able to afford a new median priced new home. A $1,000 home price increase would make 117,932 more households disqualify for the new home mortgage. Home prices surged during the pandemic, creating affordability challenges, particularly for first-time buyers.

Other NAHB estimates in this paper show that for 2022, 25 basis points added to the mortgage rate at 30-year fixed rate of 3.5% would price out around 1.1 million households. In addition to the national numbers, NAHB once again is providing priced out estimates for individual states and more than 300 metropolitan areas.

The Priced-Out Methodology and Data

The NAHB priced-out model uses the ability to qualify a mortgage to measure housing affordability, because most home buyers finance their new home purchase with conventional loans, and because convenient underwriting standards for these loans apply. The standard NAHB adopts for its priced-out estimates is that the sum of the mortgage payment (including the principal amount, loan interest, property tax, homeowners' property and private mortgage insurance premiums (PITI), is no more than 28 percent of monthly gross household income.

As a result, the number of households that qualify for mortgages for a certain priced home depends on the household income distribution in an area and the mortgage interest rate at that

[1] The 2022 US median new home price is estimated by projecting the 2021 preliminary median new home price using the NAHB forecast of the Case-Shiller Home Price Index.

time. The most recent detailed household income distributions for all states and metro areas are from the 2019[2] American Community Survey (ACS). NAHB adjusts the income distributions to reflect the income and population changes that may happen from 2019 to 2022. The income distribution is adjusted for inflation using the 2021 median family income at the state[3] and metro[4] levels and then extrapolated into 2022. The number of households in 2022 is projected by the growth rate of households from 2018 to 2019.

Other assumptions of the priced-out calculation include a 10% down payment and a 30-year fixed rate mortgage at an interest rate of 2.8% with zero points. For a loan with this down payment, private mortgage insurance is required by lenders and thus included as part of PITI. The typical private mortgage insurance annual premium is 73 basis points,[5] based on the standard assumption of a national median credit score of 738[6] and 10% down payment and 30-year fixed mortgage rate. Effective local property tax rates are calculated using data from the 2019 American Community Survey (ACS) summary files. Homeowner insurance rates are constructed from the 2019 ACS Public Use Microdata Sample (PUMS)[7]. For the US as a whole, the effective property tax rate is $10.7 per $1,000 of property value and typical homeowner insurance is $3.6 per $1,000 of property value.

U.S. Priced-Out Estimates

Under these assumptions, 39 million (about 31%) of the 126.7 million US households could afford to buy a new median priced home at $412,505 in 2022. A $1,000 home price increase will thus price 117,932 households out of the market for this home. These are the households that can qualify for a mortgage before a $1,000 increase but not afterwards, as shown in Table 1 below.

[2] We used the standard 2019 1-year ACS data, because the experimental 2020 1-year ACS may have some potential issues on some estimates and also doesn't cover the metro level estimates due to the disruptions of data collection during the pandemic.
[3] The state median family income is published by Department of Housing and Urban Development (HUD).
[4] The MSA median family income is calculated by HUD and published by Federal Financial Institutions Examination Council (FFIEC).
[5] Private mortgage insurance premium (PMI) is obtained from the PMI Cost Calculator(https://www.hsh.com/calc-pmionly.html)
[6] Median credit score information is shown in the article "Four ways today's high home prices affect the larger economy" October 2018 Urban Institute https://www.urban.org/urban-wire/four-ways-todays-high-home-prices-affect-larger-economy
[7] Producing metro level estimates from the ACS PUMS involves aggregating Public Use Microdata Area (PUMA) level data according to the latest definitions of metropolitan areas. Due to complexity of these procedures and since metro level insurance rates tend to remain stable over time, NAHB revises these estimates only periodically.

Table 1. US Households Priced Out of the Market by Increases in House Prices, 2022

Area	Mortgage Rate	House Price	Monthly Mortgage Payment	Taxes and Insurance	Minimum Income Needed	Households That Can Afford House	Households That Cannot Afford House
United States	3.50%	$412,506	$1,822	$493	$99,205	39,205,292	87,527,382
United States	3.50%	$413,506	$1,826	$494	$99,445	39,087,360	87,645,314
Difference		$1,000	$4	$1	$240	-117,932	117,932

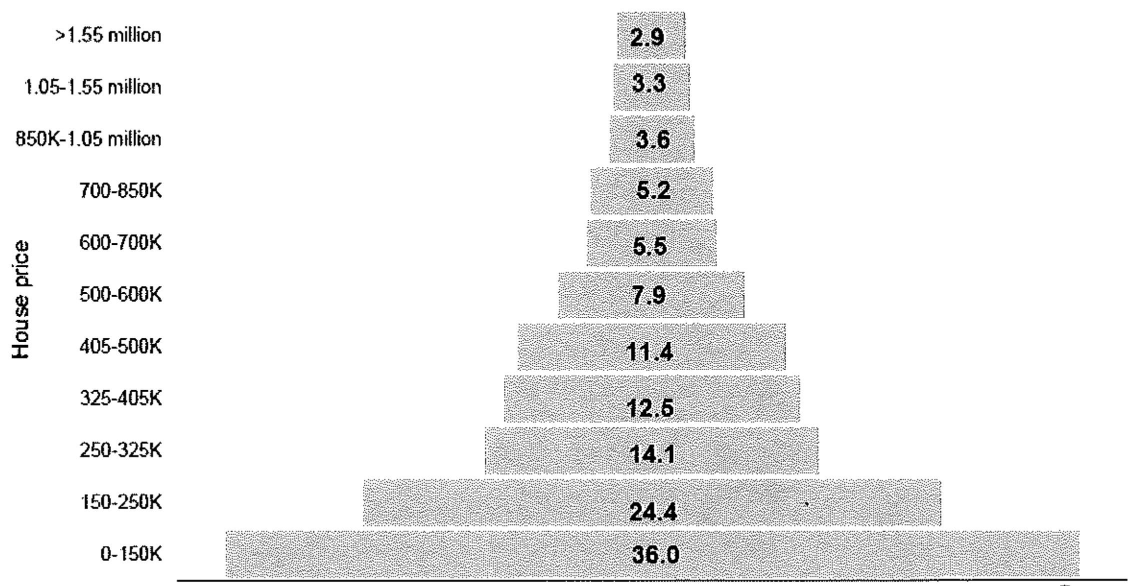
Calculations assume a 10% down payment and a 73 basis point fee for private mortgage insurance.
A Household Qualifies for a Mortgage if Mortgage Payments, Taxes, and Insurance are 28% of Income

US Household Income Distribution for 2022

Income Range:			Households	Cumulative
$0	to	$9,806	7,346,720	7,346,720
$9,807	to	$14,710	5,098,688	12,445,408
$14,711	to	$19,613	4,993,521	17,438,928
$19,614	to	$24,517	5,492,472	22,931,400
$24,518	to	$29,420	5,143,791	28,075,191
$29,421	to	$34,324	5,491,210	33,566,400
$34,325	to	$39,228	5,091,265	38,657,665
$39,229	to	$44,131	5,277,777	43,935,442
$44,132	to	$49,035	4,768,527	48,703,969
$49,036	to	$58,842	9,371,391	58,075,361
$58,843	to	$73,553	12,639,876	70,715,236
$73,554	to	$98,071	16,256,580	86,971,817
$98,072	to	$122,588	12,022,980	98,994,796
$122,589	to	$147,106	7,897,653	106,892,450
$147,107	to	$196,142	9,084,459	115,976,909
$196,143	to	More	10,755,766	126,732,674

The U.S. housing affordability pyramid represents the number of households that could only afford homes of no more than a certain price. Based on conventional assumptions and underwriting standards, the minimum income required to purchase a $150,000 home is $36,074. In 2022, about 36 million households in the U.S. are estimated to have incomes no more than that threshold and, therefore, can only afford to buy homes priced no more than $150,000. These 36 million households form the bottom step of the pyramid (Figure 1). Of the remaining households who can afford a home priced at $150,000, 24.4 million can only afford to pay a top price of somewhere between $150,000 and $250,000 (the second step on the pyramid). Each step represents a maximum affordable price range for fewer and fewer households. Housing affordability is a great concern for households with annual income at the lower end of the distribution.

Figure 1. US Households (In Millions)
by Highest Priced Home They Can Afford Based on Income: 2022



Source: Calculations by the National Association of Homebuilders Housing Policy Department, based on income data from the 2019 American Community Survey Public Use Microdata Sample File, U.S. Census Bureau

NAHB. National Association of Home Builders

State and Local Estimates

The number of priced out households varies across both states and metropolitan areas, largely affected by the sizes of local population and the affordability of new homes. The 2022 priced-out estimates for all states and the District of Columbia are shown in Table 2, which presents the projected 2022 median new home price estimates and the amount of income needed to qualify the mortgage, the number of households who can and who cannot afford the new homes, and the number of households could be priced out if price goes up by $1,000. Among all the states, California registered the largest number of households priced out of the market by a $1,000 increase in the median-priced home in the state (12,411), followed by Texas (11,108), and Florida (6,931), largely because these three states are the top three populous states. Households in California, where half of all new homes are sold for less than $543,767, need an annual income of at least $120,445 to qualify for a new home mortgage. Therefore, around 9.2 million households (68.9% of all households) in California do not earn enough income to qualify for new home loan initially. In contrast, households in West Virginia only need to have a household income of $69,855 to qualify new home loans. Only 34% of households in West Virginia (around 239,830 households) cannot afford new homes at the median price of $306,339 in 2022.

Table 3 shows the 2022 priced-out estimates for 387 metropolitan statistical areas. The metropolitan area with the largest priced out effect, in terms of absolute numbers, is New York-Newark-Jersey City, NY-NJ-PA, where 4,734 households will be disqualified for a new median-priced home if price goes up by $1,000. The Chicago-Naperville-Elgin, IL-IN-WI metro area registers the second largest number of priced-out households (4,273), followed by Philadelphia-Camden-Wilmington, PA-NJ-DE-MD metro area (3,235). Different impacts of adding $1,000 to a new home price are largely due to different sizes of metro population and the affordability of new homes to begin with. The largest priced-out effect is in the New York metro area, where the median priced new homes are only affordability to 14% of households, is largely because of its status of have the largest population size among all metro areas (6.6 million households). Compared to the New York metro, the populations in the Chicago and Houston metro areas are much smaller. The Chicago metro area only has half of the New York metro population and the Philadelphia metro area has 25%. However, median priced homes in Chicago or Philadelphia metro areas are relatively more affordable initially. Around 33% of households in Chicago and 45% households in Philadelphia metro area are capable of buying new median-priced homes there.

Interest Rates

The NAHB 2022 priced-out estimates also present how interest rates affect the number of households that would be priced out of the new home market. If mortgage interest rate increase, the monthly mortgage payments will rise as well and therefore higher household income thresholds are needed to qualify for a mortgage loan. Table 4 shows the number of households priced out of the market for a new median priced home at $412,505 by each 25 basis-point increase in interest rate from 1.5% to 9.5%. When interest rates increase from 1.75% to 2.00%, around 1.4 million households can no longer afford buying median-priced new homes. An increase from 3.00% to 3.25% prices approximately 1.5 million households out of the market. However, about 539,000 households would be squeezed out of the market if interest rate goes up to 9% from 8.75%. This diminishing effect happens because only a few households at the smaller end of household income distribution will be affected. In contrast, when interest rates are relatively low, a 25 basis-point increase would affect a larger number of households at the larger section of the income distribution.

Table 4. U.S. Households Priced Out of the Market by an Increase in Interest Rates, 2022

Mortgage Rate	Median New House Price	Monthly Mortgage Payment	Taxes and Insurance	Minimum Income Needed	Households That Can Afford House	Change in Households	Cumulative Change
1.50%	$412,505	$1,415	$493	$81,775	50,566,246		
1.75%	$412,505	$1,463	$493	$83,820	49,210,076	-1,356,170	-1,356,170
2.00%	$412,505	$1,512	$493	$85,905	47,827,984	-1,382,092	-2,738,262
2.25%	$412,505	$1,561	$493	$88,028	46,420,275	-1,407,709	-4,145,971
2.50%	$412,505	$1,612	$493	$90,189	44,987,280	-1,432,995	-5,578,966
2.75%	$412,505	$1,663	$493	$92,388	43,529,350	-1,457,930	-7,036,896
3.00%	$412,505	$1,715	$493	$94,624	42,046,857	-1,482,493	-8,519,389
3.25%	$412,505	$1,768	$493	$96,896	40,540,195	-1,506,662	-10,026,051
3.50%	$412,505	$1,822	$493	$99,204	39,205,373	-1,334,822	-11,360,873
3.75%	$412,505	$1,877	$493	$101,548	38,056,255	-1,149,118	-12,509,991
4.00%	$412,505	$1,932	$493	$103,926	36,890,209	-1,166,046	-13,676,037
4.25%	$412,505	$1,988	$493	$106,337	35,707,574	-1,182,635	-14,858,672
4.50%	$412,505	$2,045	$493	$108,782	34,508,699	-1,198,875	-16,057,547
4.75%	$412,505	$2,103	$493	$111,259	33,293,939	-1,214,760	-17,272,307
5.00%	$412,505	$2,162	$493	$113,768	32,063,657	-1,230,282	-18,502,589
5.25%	$412,505	$2,221	$493	$116,308	30,818,224	-1,245,433	-19,748,022
5.50%	$412,505	$2,281	$493	$118,878	29,558,014	-1,260,210	-21,008,232
6.00%	$412,505	$2,403	$493	$124,105	27,249,752	-2,308,262	-23,316,494
6.25%	$412,505	$2,465	$493	$126,760	26,394,326	-855,426	-24,171,920
6.50%	$412,505	$2,528	$493	$129,443	25,530,198	-864,128	-25,036,048
6.75%	$412,505	$2,591	$493	$132,152	24,657,622	-872,576	-25,908,624
7.00%	$412,505	$2,655	$493	$134,886	23,776,850	-880,772	-26,789,396
7.25%	$412,505	$2,719	$493	$137,645	22,888,135	-888,715	-27,678,111
7.50%	$412,505	$2,784	$493	$140,428	21,991,728	-896,407	-28,574,518
7.75%	$412,505	$2,849	$493	$143,234	21,087,877	-903,851	-29,478,369
8.00%	$412,505	$2,915	$493	$146,062	20,176,829	-911,048	-30,389,417
8.25%	$412,505	$2,982	$493	$148,912	19,505,842	-670,987	-31,060,404
8.50%	$412,505	$3,049	$493	$151,783	18,974,005	-531,837	-31,592,241
8.75%	$412,505	$3,116	$493	$154,674	18,438,444	-535,561	-32,127,802
9.00%	$412,505	$3,184	$493	$157,584	17,899,294	-539,150	-32,666,952
9.25%	$412,505	$3,253	$493	$160,513	17,356,685	-542,609	-33,209,561
9.50%	$412,505	$3,321	$493	$163,460	16,810,748	-545,937	-33,755,498

Table 2 Households Priced Out of the Market by a $1,000 Price Increase, 2022

State	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford Median Price	Households: Who Can't Afford Median Price	Priced Out
United States	412,505	99,205	126,732,674	39,205,292	87,527,382	117,932
Alabama	389,820	87,513	2,030,653	585,268	1,445,385	2,019
Alaska	592,752	145,654	245,273	52,520	192,753	185
Arizona	464,413	102,987	2,846,208	738,906	2,107,302	2,417
Arkansas	397,926	92,827	1,185,825	247,459	938,366	1,323
California	543,767	120,445	13,418,516	4,171,589	9,246,927	12,411
Colorado	539,922	118,177	2,419,693	678,245	1,741,448	2,373
Connecticut	569,691	159,690	1,374,395	295,752	1,078,643	722
Delaware	214,329	47,202	403,160	258,871	144,289	694
District of Columbia	705,027	151,871	304,205	85,272	218,933	152
Florida	422,108	100,752	8,202,464	2,048,794	6,153,670	6,931
Georgia	356,743	84,551	4,005,751	1,449,552	2,556,199	4,851
Hawaii	856,262	176,306	496,603	87,242	409,361	200
Idaho	402,374	89,371	704,941	193,828	511,113	954
Illinois	365,711	102,703	4,869,434	1,490,121	3,379,313	5,726
Indiana	370,500	88,007	2,593,558	789,096	1,804,462	3,217
Iowa	371,169	97,601	1,347,055	390,191	956,864	1,943
Kansas	411,450	108,523	1,153,221	260,181	893,040	1,209
Kentucky	369,690	88,143	1,797,683	474,190	1,323,493	2,187
Louisiana	367,716	86,125	1,752,695	512,485	1,240,210	1,917
Maine	464,093	115,349	583,667	110,801	472,866	554
Maryland	371,232	88,336	2,259,582	1,121,922	1,137,660	2,813
Massachusetts	608,827	146,813	2,731,440	687,723	2,043,717	1,468
Michigan	350,069	89,906	4,007,356	1,241,683	2,765,673	5,445
Minnesota	411,914	100,952	2,309,096	797,198	1,511,898	2,520
Mississippi	327,125	79,616	1,075,406	307,232	768,174	1,125
Missouri	363,418	88,621	2,530,303	747,029	1,783,274	3,273
Montana	375,244	87,237	456,886	136,905	319,981	582
Nebraska	321,924	87,060	789,585	270,038	519,547	1,250
Nevada	438,564	95,031	1,185,810	356,167	829,643	1,462
New Hampshire	522,209	143,126	573,134	124,665	448,469	461
New Jersey	321,921	92,227	3,398,860	1,616,994	1,781,866	4,734
New Mexico	446,296	102,908	791,404	163,836	627,568	559
New York	526,661	136,643	7,691,427	1,742,276	5,949,151	5,455
North Carolina	369,458	85,781	4,152,837	1,308,399	2,844,438	5,019
North Dakota	386,330	94,304	336,340	118,726	217,614	411
Ohio	392,571	101,746	4,867,616	1,225,401	3,642,215	4,479
Oklahoma	397,634	99,038	1,525,067	339,386	1,185,681	1,290
Oregon	533,740	122,608	1,677,821	355,490	1,322,331	1,073
Pennsylvania	411,744	105,800	5,266,983	1,430,479	3,836,504	5,095
Rhode Island	485,255	126,065	408,982	87,707	321,275	307
South Carolina	398,515	90,074	2,126,954	591,748	1,535,206	2,514
South Dakota	332,563	83,931	380,080	124,008	256,072	536
Tennessee	390,969	89,349	2,815,746	787,785	2,027,961	3,343
Texas	395,451	107,240	10,639,459	2,814,421	7,825,038	11,108
Utah	462,359	100,782	1,102,553	370,426	732,127	1,164
Vermont	498,757	133,782	266,994	43,964	223,030	176
Virginia	352,164	80,457	3,241,321	1,546,335	1,694,986	3,871
Washington	565,613	130,409	3,046,029	739,860	2,306,169	2,182
West Virginia	306,339	69,855	708,937	239,830	469,107	1,037
Wisconsin	394,639	103,737	2,431,158	614,779	1,816,379	2,761
Wyoming	643,010	143,774	241,973	34,538	207,435	134

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford	Households: Who Can't Afford	Households: Priced Out
Abilene, TX	370,260	97,759	62,424	10,618	51,806	55
Akron, OH	620,647	163,679	281,497	40,328	241,169	130
Albany, GA	210,102	54,145	47,979	18,652	29,327	67
Albany-Lebanon, OR	477,331	114,312	52,348	5,477	46,871	32
Albany-Schenectady-Troy, NY	453,699	125,344	390,092	94,671	295,421	425
Albuquerque, NM	441,549	105,422	342,241	75,583	266,658	287
Alexandria, LA	408,861	95,832	57,007	13,234	43,773	47
Allentown-Bethlehem-Easton, PA-NJ	386,349	105,230	327,762	100,262	227,500	395
Altoona, PA	347,794	85,693	56,935	18,626	38,309	63
Amarillo, TX	417,714	115,424	98,870	21,387	77,483	102
Ames, IA	426,010	110,843	122,990	21,514	101,476	100
Anchorage, AK	616,135	153,196	139,296	28,178	111,118	120
Ann Arbor, MI	387,260	99,670	137,585	52,784	84,801	185
Anniston-Oxford, AL	249,778	57,517	45,771	20,351	25,420	84
Appleton, WI	395,745	104,592	95,319	25,559	69,760	116
Asheville, NC	475,109	105,580	198,214	44,588	153,626	142
Athens-Clarke County, GA	418,267	99,477	91,349	20,710	70,639	68
Atlanta-Sandy Springs-Alpharetta, GA	374,340	88,463	2,353,055	952,462	1,400,593	2,955
Atlantic City-Hammonton, NJ	464,630	143,861	118,554	24,662	93,892	78
Auburn-Opelika, AL	459,346	103,248	82,582	18,123	64,459	56
Augusta-Richmond County, GA-SC	328,711	76,632	205,682	81,080	124,602	312
Austin-Round Rock-Georgetown, TX	503,446	136,067	921,210	240,753	680,457	791
Bakersfield, CA	468,706	110,346	272,053	55,414	216,639	233
Baltimore-Columbia-Towson, MD	370,465	88,708	1,089,357	522,845	566,512	1,319
Bangor, ME	401,583	102,531	71,630	10,161	61,469	72
Barnstable Town, MA	923,338	213,849	133,245	(3,836)	137,081	77
Baton Rouge, LA	383,656	89,358	317,547	98,014	219,533	397
Battle Creek, MI	326,691	86,334	53,567	11,669	41,898	78
Bay City, MI	337,186	105,195	46,165	7,114	39,051	51
Beaumont-Port Arthur, TX	313,411	86,917	133,516	35,677	97,839	205
Beckley, WV	242,427	56,167	50,601	18,925	31,676	64
Bellingham, WA	555,365	124,815	94,141	13,143	80,998	62
Bend, OR	617,944	137,621	67,116	10,451	56,665	37
Billings, MT	332,173	78,598	100,611	39,283	61,328	108
Binghamton, NY	314,801	96,331	110,794	27,848	82,946	180
Birmingham-Hoover, AL	482,037	108,820	407,863	94,362	313,501	361
Bismarck, ND	439,498	105,819	42,050	13,577	28,473	50
Blacksburg-Christiansburg, VA	336,030	76,244	46,490	15,710	30,780	96
Blacksburg-Christiansburg, VA	336,030	76,244	46,490	15,710	30,780	96
Bloomington, IL	314,387	92,786	45,136	14,960	30,176	75
Bloomington, IN	361,796	85,128	53,191	13,354	39,837	74
Bloomsburg-Berwick, PA	400,528	100,008	31,634	9,110	22,524	41
Boise City, ID	475,590	105,816	299,102	72,774	226,328	277
Boston-Cambridge-Newton, MA-NH	659,214	159,304	1,879,865	517,553	1,362,312	1,060
Boulder, CO	807,426	174,316	143,134	33,245	109,889	61
Bowling Green, KY	358,988	84,324	63,108	18,033	45,075	71
Bremerton-Silverdale-Port Orchard, WA	596,700	136,959	114,125	25,802	88,323	87
Bridgeport-Stamford-Norwalk, CT	969,197	256,114	325,769	32,051	293,718	189
Brownsville-Harlingen, TX	205,709	58,960	143,787	48,265	95,522	243
Brunswick, GA	478,163	112,909	49,150	9,656	39,494	32
Buffalo-Cheektowaga, NY	560,710	162,718	516,476	53,651	462,825	202
Burlington, NC	285,358	66,161	63,178	25,320	37,858	137
Burlington-South Burlington, VT	557,489	145,847	97,897	15,842	82,055	42
California-Lexington Park, MD	409,726	97,025	37,684	20,843	16,841	41
Canton-Massillon, OH	339,446	86,352	172,156	49,055	123,101	223
Cape Coral-Fort Myers, FL	368,241	88,990	304,576	92,085	212,491	451

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households All	Who Can Afford	Who Can't Afford	Priced Out
Cape Girardeau, MO-IL	378,262	89,998	52,532	8,451	44,081	53
Carbondale-Marion, IL	185,141	51,481	75,999	32,482	43,517	165
Carson City, NV	457,059	95,996	21,555	6,546	15,009	23
Casper, WY	409,649	92,312	35,578	12,264	23,314	49
Cedar Rapids, IA	235,396	62,608	122,486	69,918	52,568	249
Chambersburg-Waynesboro, PA	406,228	100,082	61,556	12,378	49,178	68
Champaign-Urbana, IL	380,765	108,313	68,992	16,316	52,676	61
Charleston, WV	166,635	39,099	192,163	114,037	78,126	365
Charleston-North Charleston, SC	444,796	100,016	334,532	100,413	234,119	343
Charlotte-Concord-Gastonia, NC-SC	406,068	93,525	1,051,128	317,963	733,165	984
Charlottesville, VA	436,512	98,832	82,950	25,978	56,972	86
Chattanooga, TN-GA	345,597	80,807	228,491	81,601	146,890	356
Cheyenne, WY	376,930	85,191	48,587	18,634	29,953	72
Chicago-Naperville-Elgin, IL-IN-WI	385,284	107,672	3,542,395	1,168,740	2,373,655	4,273
Chico, CA	451,705	102,054	52,210	10,886	41,324	47
Cincinnati, OH-KY-IN	359,070	91,187	928,803	300,805	627,998	1,118
Clarksville, TN-KY	232,271	55,244	154,298	74,661	79,637	305
Cleveland, TN	333,474	76,845	47,413	12,665	34,748	74
Cleveland-Elyria, OH	414,850	113,218	892,689	198,729	693,960	793
Coeur d'Alene, ID	497,238	108,535	66,277	7,515	58,762	30
College Station-Bryan, TX	333,039	89,362	94,543	28,536	66,007	141
Colorado Springs, CO	644,030	141,936	288,402	44,036	244,366	116
Columbia, MO	385,849	93,405	109,445	31,836	77,609	155
Columbia, SC	358,760	82,576	326,878	101,515	225,363	425
Columbus, GA-AL	228,129	55,001	136,505	62,040	74,465	242
Columbus, IN	343,559	81,094	26,274	8,646	17,628	54
Columbus, OH	398,828	103,510	864,699	251,794	612,905	969
Corpus Christi, TX	418,311	118,371	129,850	19,357	110,493	100
Corvallis, OR	532,862	125,183	43,556	8,741	34,815	35
Crestview-Fort Walton Beach-Destin, FL	638,703	148,742	87,046	10,590	76,456	23
Cumberland, MD-WV	385,887	91,418	32,371	5,003	27,368	45
Dallas-Fort Worth-Arlington, TX	445,150	122,350	2,668,719	763,144	1,905,575	2,800
Dalton, GA	245,341	57,425	48,066	20,374	27,692	95
Danville, IL	246,170	70,123	34,316	11,216	23,100	60
Daphne-Fairhope-Foley, AL	409,307	90,223	78,895	23,765	55,130	97
Davenport-Moline-Rock Island, IA-IL	312,842	87,089	160,052	51,906	108,146	241
Decatur, AL	364,671	82,853	63,893	18,964	44,929	68
Decatur, IL	380,970	106,780	37,712	4,631	33,081	40
Deltona-Daytona Beach-Ormond Beach, FL	485,316	115,511	276,985	45,011	231,974	217
Denver-Aurora-Lakewood, CO	619,950	136,810	1,217,976	323,273	894,703	911
Des Moines-West Des Moines, IA	399,241	107,783	370,747	105,957	264,790	450
Detroit-Warren-Dearborn, MI	382,726	98,852	1,750,729	508,048	1,242,681	1,735
Dothan, AL	409,015	91,859	61,092	15,133	45,959	63
Dover, DE	289,057	63,009	68,572	31,760	36,812	124
Dubuque, IA	420,038	109,329	37,881	8,400	29,481	39
Duluth, MN-WI	293,191	72,605	151,133	54,713	96,420	219
Durham-Chapel Hill, NC	403,951	95,244	369,332	117,983	251,349	484
East Stroudsburg, PA	473,477	138,179	59,919	12,252	47,667	52
Eau Claire, WI	383,493	98,953	68,004	17,713	50,291	85
El Centro, CA	373,511	87,749	73,983	18,427	55,556	93
Elizabethtown-Fort Knox, KY	336,249	79,983	63,304	17,208	46,096	77
Elkhart-Goshen, IN	347,842	82,359	55,260	13,576	41,684	74
Elmira, NY	333,791	100,836	31,105	6,787	24,318	34
El Paso, TX	414,875	121,837	267,203	23,615	243,588	116
Enid, OK	611,310	156,209	25,863	1,195	24,668	7
Erie, PA	391,807	105,418	111,127	18,258	92,869	114

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford	Households: Who Can't Afford	Households: Priced Out
Eugene-Springfield, OR	484,241	112,537	154,573	24,704	129,869	143
Evansville, IN-KY	423,341	102,044	133,922	33,573	100,349	180
Fairbanks, AK	656,901	164,416	33,200	7,091	26,109	15
Fargo, ND-MN	396,228	99,032	119,902	34,882	85,020	157
Farmington, NM	436,529	99,068	39,300	7,951	31,349	26
Fayetteville, NC	333,142	82,321	447,518	110,395	337,123	551
Fayetteville-Springdale-Rogers, AR	460,194	106,625	172,998	38,180	134,818	147
Fayetteville-Springdale-Rogers, AR	460,194	106,625	172,998	38,180	134,818	147
Flagstaff, AZ	438,500	94,920	54,531	17,031	37,500	51
Flint, MI	321,404	85,821	168,583	45,923	122,660	210
Florence, SC	256,906	58,043	84,243	36,438	47,805	147
Florence-Muscle Shoals, AL	210,272	47,895	63,635	32,722	30,913	160
Fond du Lac, WI	437,776	115,892	47,771	5,007	42,764	51
Fort Collins, CO	527,405	115,120	170,752	45,447	125,305	161
Fort Smith, AR-OK	329,273	77,137	72,539	17,040	55,499	77
Fort Wayne, IN	372,538	89,282	129,584	36,235	93,349	167
Fresno, CA	584,761	134,146	336,158	43,725	292,433	145
Gadsden, AL	209,631	47,701	44,662	24,190	20,472	74
Gainesville, FL	410,251	99,444	221,838	43,128	178,710	174
Gainesville, GA	366,597	85,536	67,567	25,918	41,649	77
Gettysburg, PA	362,831	94,068	36,214	11,337	24,877	66
Glens Falls, NY	441,248	119,282	59,093	11,679	47,414	60
Goldsboro, NC	294,732	72,913	46,906	11,388	35,518	70
Grand Forks, ND-MN	348,302	86,027	50,039	14,336	35,703	66
Grand Island, NE	325,283	86,905	24,873	7,446	17,427	38
Grand Junction, CO	373,357	79,812	69,351	21,267	48,084	83
Grand Rapids-Kentwood, MI	367,825	91,458	395,458	118,360	277,098	611
Grand Rapids-Kentwood, MI	367,825	91,458	395,458	118,360	277,098	611
Grants Pass, OR	497,786	109,244	30,185	5,653	24,532	24
Great Falls, MT	450,976	109,521	25,795	3,666	22,129	18
Greeley, CO	456,657	100,415	122,049	44,315	77,734	137
Green Bay, WI	384,514	99,584	141,478	40,086	101,392	187
Greensboro-High Point, NC	386,866	91,613	299,819	81,678	218,141	340
Greenville, NC	374,077	90,924	76,076	15,346	60,730	76
Greenville-Anderson, SC	404,144	90,368	364,336	114,743	249,593	414
Gulfport-Biloxi, MS	324,706	79,714	171,894	47,367	124,527	208
Gulfport-Biloxi, MS	324,706	79,714	171,894	47,367	124,527	208
Hagerstown-Martinsburg, MD-WV	347,075	80,258	139,315	56,893	82,422	211
Hammond, LA	298,607	68,268	43,997	16,534	27,463	58
Hanford-Corcoran, CA	488,216	111,900	48,012	10,586	37,426	27
Harrisburg-Carlisle, PA	374,826	95,681	236,702	75,543	161,159	363
Harrisonburg, VA	466,109	104,015	44,529	8,528	36,001	41
Hartford-East Hartford-Middletown, CT	430,909	123,575	496,012	155,817	340,195	561
Hattiesburg, MS	331,821	81,449	77,482	22,297	55,185	54
Hickory-Lenoir-Morganton, NC	383,566	87,947	149,878	31,870	118,008	185
Hilton Head Island-Bluffton, SC	545,253	123,117	84,253	15,074	69,179	36
Hinesville, GA	345,070	85,591	26,330	5,032	21,298	36
Homosassa Springs, FL	333,217	79,016	71,371	13,907	57,464	100
Hot Springs, AR	400,506	92,273	46,022	11,667	34,355	36
Houma-Thibodaux, LA	411,906	95,482	87,329	26,471	60,858	93
Houston-The Woodlands-Sugar Land, TX	376,904	105,106	2,683,433	834,903	1,848,530	2,966
Huntington-Ashland, WV-KY-OH	249,429	58,891	136,441	56,025	80,416	249
Huntsville, AL	313,890	70,250	196,689	94,727	101,962	246
Idaho Falls, ID	356,957	80,508	53,623	19,907	33,716	71
Indianapolis-Carmel-Anderson, IN	404,891	96,718	825,931	238,887	587,044	777
Iowa City, IA	374,690	98,512	71,638	23,645	47,993	97

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford	Households: Who Can't Afford	Households: Priced Out
Ithaca, NY	463,846	137,763	40,539	7,126	33,413	24
Jackson, MI	284,020	73,544	57,953	14,618	43,335	126
Jackson, MS	425,861	103,169	247,128	53,040	194,088	184
Jackson, TN	374,772	90,509	189,959	39,996	149,963	183
Jacksonville, FL	350,907	83,189	612,100	225,298	386,802	834
Jacksonville, NC	250,034	60,538	54,821	25,743	29,078	113
Janesville-Beloit, WI	299,387	81,697	67,412	23,048	44,364	113
Jefferson City, MO	319,795	76,319	68,525	24,160	44,365	106
Johnson City, TN	324,625	74,167	100,725	27,527	73,198	96
Johnstown, PA	419,745	109,351	56,511	7,739	48,772	45
Jonesboro, AR	261,735	61,617	48,271	15,085	33,186	102
Joplin, MO	208,466	50,209	56,519	28,802	27,717	122
Kahului-Wailuku-Lahaina, HI	860,115	174,727	60,840	10,408	50,432	24
Kalamazoo-Portage, MI	340,703	89,565	48,379	15,765	32,614	70
Kankakee, IL	254,208	73,948	36,569	14,901	21,668	68
Kansas City, MO-KS	406,503	103,323	872,579	261,457	611,122	951
Kennewick-Richland, WA	569,733	132,312	110,899	22,629	88,270	80
Killeen-Temple, TX	310,708	85,798	172,850	46,540	126,310	260
Kingsport-Bristol, TN-VA	331,370	75,781	147,713	39,611	108,102	174
Kingston, NY	503,989	141,431	70,046	14,528	55,518	57
Knoxville, TN	359,502	81,161	357,924	107,482	250,442	481
Kokomo, IN	326,584	78,370	31,351	11,299	20,052	49
La Crosse-Onalaska, WI-MN	408,355	107,791	57,603	12,929	44,674	45
Lafayette, LA	332,491	77,517	184,181	63,713	120,468	229
Lafayette-West Lafayette, IN	350,480	81,946	117,680	35,963	81,717	118
Lake Charles, LA	296,693	69,613	76,922	30,979	45,943	101
Lake Havasu City-Kingman, AZ	364,962	80,352	93,616	22,344	71,272	107
Lakeland-Winter Haven, FL	336,604	80,168	231,163	70,568	160,595	288
Lancaster, PA	362,483	93,250	211,480	73,852	137,628	337
Lansing-East Lansing, MI	343,268	91,689	332,879	99,022	233,857	459
Laredo, TX	264,345	77,020	79,489	23,158	56,331	155
Las Cruces, NM	444,017	101,531	75,277	10,697	64,580	48
Las Vegas-Henderson-Paradise, NV	427,687	92,821	828,799	252,480	576,319	998
Lawrence, KS	488,696	126,480	47,330	7,403	39,927	30
Lawton, OK	310,252	78,670	42,706	15,595	27,111	59
Lebanon, PA	334,562	87,105	51,926	16,646	35,280	80
Lewiston, ID-WA	333,706	77,536	32,532	9,072	23,460	53
Lewiston-Auburn, ME	394,501	103,483	49,148	10,023	39,125	58
Lexington-Fayette, KY	393,855	93,338	210,462	58,692	151,770	273
Lima, OH	319,328	81,831	38,308	8,787	29,521	78
Lincoln, NE	341,637	92,054	142,430	46,638	95,792	189
Little Rock-North Little Rock-Conway, AR	380,758	90,676	301,484	85,219	216,265	341
Logan, UT-ID	399,881	89,613	50,275	15,604	34,671	68
Longview, TX	487,551	123,345	251,877	38,118	213,759	141
Longview, WA	481,870	110,966	41,356	8,583	32,773	29
Los Angeles-Long Beach-Anaheim, CA	827,177	181,947	4,428,273	475,469	3,952,804	2,063
Louisville/Jefferson County, KY-IN	329,897	78,521	460,321	171,654	288,667	608
Lubbock, TX	371,241	104,029	127,125	29,393	97,732	140
Lynchburg, VA	295,934	66,107	101,697	47,434	54,263	141
Macon-Bibb County, GA	301,272	76,810	89,437	24,508	64,929	125
Madera, CA	514,218	117,287	44,097	7,150	36,947	34
Madison, WI	458,221	120,626	289,531	71,378	218,153	358
Manchester-Nashua, NH	452,427	124,252	165,438	47,372	118,066	133
Manhattan, KS	418,768	108,437	101,173	17,231	83,942	118
Mankato, MN	341,398	83,818	41,418	13,131	28,287	71
Mansfield, OH	359,728	93,655	55,305	8,885	46,420	92

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McAllen-Edinburg-Mission, TX	335,633	95,447	280,925	46,129	234,796	214
Medford, OR	515,510	117,083	82,099	14,693	67,406	56
Memphis, TN-MS-AR	377,236	92,760	507,779	132,324	375,455	639
Merced, CA	498,885	111,350	84,221	17,902	66,319	76
Miami-Fort Lauderdale-Pompano Beach, FL	540,455	131,314	2,325,093	300,137	2,024,956	840
Michigan City-La Porte, IN	392,072	94,563	43,034	11,641	31,393	46
Midland, MI	286,928	77,533	35,139	10,835	24,304	76
Midland, TX	287,752	73,390	67,505	34,192	33,313	85
Milwaukee-Waukesha, WI	516,115	134,610	638,219	106,816	531,403	445
Minneapolis-St. Paul-Bloomington, MN-WI	416,273	102,577	1,425,093	516,845	908,248	1,775
Missoula, MT	473,828	112,440	52,233	9,720	42,513	39
Mobile, AL	355,811	84,116	169,244	43,706	125,538	167
Modesto, CA	482,654	108,785	173,287	38,869	134,418	164
Monroe, LA	415,284	94,652	130,554	28,409	102,145	100
Monroe, MI	295,480	74,362	58,791	25,849	32,942	102
Montgomery, AL	391,315	87,155	153,087	43,901	109,186	148
Morgantown, WV	461,690	102,650	52,997	11,351	41,646	51
Morristown, TN	424,836	95,323	116,212	15,200	101,012	123
Mount Vernon-Anacortes, WA	566,632	131,062	50,790	11,191	39,599	45
Muncie, IN	337,031	83,071	46,641	10,293	36,348	54
Muskegon, MI	279,043	72,562	63,101	20,848	42,253	112
Myrtle Beach-Conway-North Myrtle Beach, SC-NC	322,745	72,444	234,589	78,923	155,666	303
Napa, CA	955,131	213,065	50,563	5,394	45,169	28
Naples-Marco Island, FL	664,399	152,806	130,325	23,840	106,485	48
Nashville-Davidson--Murfreesboro--Franklin, TN	450,473	100,736	743,099	199,878	543,221	773
Nashville-Davidson--Murfreesboro--Franklin, TN	450,473	100,736	743,099	199,878	543,221	773
New Bern, NC	334,683	80,343	61,798	18,997	42,801	74
New Haven-Milford, CT	356,202	103,077	310,160	107,378	202,782	435
New Orleans-Metairie, LA	405,482	96,947	493,842	121,453	372,389	444
New York-Newark-Jersey City, NY-NJ-PA	580,632	152,406	6,588,785	925,276	5,663,509	4,734
Niles, MI	459,927	114,827	53,681	11,565	42,116	46
North Port-Sarasota-Bradenton, FL	423,143	99,565	326,791	88,268	238,523	318
Norwich-New London, CT	453,563	124,261	114,867	27,142	87,725	103
Ocala, FL	241,760	57,169	152,366	59,109	93,257	300
Ocean City, NJ	723,202	183,868	46,604	4,650	41,954	22
Odessa, TX	417,120	107,602	49,791	15,082	34,709	51
Ogden-Clearfield, UT	439,004	96,586	242,488	91,400	151,088	381
Oklahoma City, OK	419,810	107,574	529,600	114,254	415,346	555
Olympia-Lacey-Tumwater, WA	512,298	120,206	119,762	27,892	91,870	97
Omaha-Council Bluffs, NE-IA	304,964	84,769	380,160	162,848	217,312	614
Orlando-Kissimmee-Sanford, FL	451,036	106,754	931,009	219,187	711,822	785
Oshkosh-Neenah, WI	412,357	111,134	70,957	14,753	56,204	69
Owensboro, KY	184,875	45,357	54,010	28,797	25,213	104
Oxnard-Thousand Oaks-Ventura, CA	850,049	188,244	258,417	34,422	223,995	146
Palm Bay-Melbourne-Titusville, FL	515,743	122,298	241,446	50,926	190,520	174
Panama City, FL	420,213	98,644	44,032	9,319	34,713	34
Parkersburg-Vienna, WV	364,812	83,976	31,423	7,367	24,056	39
Pensacola-Ferry Pass-Brent, FL	338,034	79,657	199,646	74,205	125,441	239
Peoria, IL	398,114	116,753	214,854	38,074	176,780	158
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	316,040	82,991	2,439,618	1,111,120	1,328,498	3,235
Phoenix-Mesa-Chandler, AZ	469,193	103,235	1,873,580	558,567	1,315,013	1,688
Pine Bluff, AR	222,306	52,250	40,396	18,972	21,424	101
Pittsburgh, PA	469,412	121,503	1,073,586	217,271	856,315	1,059
Pittsfield, MA	898,333	230,126	49,747	2,657	47,090	18
Pocatello, ID	294,905	69,237	49,503	17,209	32,294	92
Portland-South Portland, ME	518,287	126,714	222,919	51,470	171,449	238

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Metro Area	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford	Households: Who Can't Afford	Households: Priced Out
Portland-Vancouver-Hillsboro, OR-WA	562,869	130,113	993,959	264,234	729,725	748
Port St. Lucie, FL	385,506	94,265	182,142	46,276	135,866	205
Providence-Warwick, RI-MA	447,415	113,948	646,042	170,883	475,159	709
Provo-Orem, UT	509,321	109,368	207,750	62,694	145,056	235
Pueblo, CO	279,782	63,695	69,707	28,486	41,221	116
Punta Gorda, FL	453,087	110,329	81,642	14,753	66,889	70
Racine, WI	465,411	124,129	85,546	14,295	71,251	72
Raleigh-Cary, NC	396,699	91,299	566,682	234,573	332,109	724
Rapid City, SD	331,433	84,402	50,719	12,554	38,165	57
Reading, PA	348,083	96,074	147,968	50,112	97,856	220
Redding, CA	546,486	125,272	88,137	10,782	77,355	40
Reno, NV	541,426	116,667	207,147	47,077	160,070	227
Richmond, VA	354,759	81,438	475,681	190,350	285,331	569
Riverside-San Bernardino-Ontario, CA	526,128	120,388	1,419,316	332,681	1,086,635	1,442
Roanoke, VA	435,426	101,006	125,817	31,040	94,777	131
Rochester, MN	378,393	94,045	104,117	41,438	62,679	136
Rochester, NY	431,433	132,970	457,754	79,284	378,470	333
Rockford, IL	252,570	77,242	135,016	52,974	82,042	203
Rocky Mount, NC	243,946	60,234	57,602	26,885	30,717	110
Rome, GA	265,062	64,481	37,860	10,747	27,113	57
Sacramento-Roseville-Folsom, CA	555,470	126,259	913,341	236,878	676,463	608
Saginaw, MI	342,243	93,061	79,987	19,702	60,285	88
St. Cloud, MN	391,100	96,370	81,272	23,166	58,106	133
St. George, UT	487,715	104,865	74,106	13,397	60,709	86
St. Joseph, MO-KS	314,214	76,394	47,387	15,585	31,802	79
St. Louis, MO-IL	391,630	100,905	1,170,246	341,278	828,968	1,201
Salem, OR	526,042	122,524	157,050	18,368	138,682	121
Salinas, CA	895,680	196,860	134,189	14,702	119,487	45
Salisbury, MD-DE	305,135	67,176	184,584	75,464	109,120	243
Salt Lake City, UT	496,180	109,120	417,420	137,635	279,785	441
San Angelo, TX	371,639	98,822	46,885	7,270	39,615	75
San Antonio-New Braunfels, TX	408,809	111,254	851,058	196,793	654,265	885
San Diego-Chula Vista-Carlsbad, CA	859,869	190,812	1,137,015	164,077	972,938	499
San Francisco-Oakland-Berkeley, CA	1,368,671	300,883	1,791,189	201,279	1,589,910	838
San Jose-Sunnyvale-Santa Clara, CA	1,680,173	365,545	659,768	(87,851)	747,619	379
San Luis Obispo-Paso Robles, CA	795,842	175,539	107,460	14,735	92,725	47
Santa Cruz-Watsonville, CA	1,235,487	269,185	106,333	6,745	99,588	45
Santa Fe, NM	471,305	102,375	60,633	16,656	43,977	35
Santa Maria-Santa Barbara, CA	1,103,681	242,435	147,194	10,940	136,254	47
Santa Rosa-Petaluma, CA	800,537	177,657	200,797	38,354	162,443	93
Savannah, GA	389,233	95,203	141,594	45,903	95,691	172
Scranton--Wilkes-Barre, PA	429,585	115,213	237,810	46,031	191,779	183
Seattle-Tacoma-Bellevue, WA	721,105	166,017	1,587,245	405,415	1,181,830	773
Sebastian-Vero Beach, FL	643,032	152,270	87,173	13,536	73,637	44
Sebring-Avon Park, FL	361,939	87,451	52,879	7,734	45,145	45
Sheboygan, WI	428,302	113,987	56,601	11,219	45,382	48
Sherman-Denison, TX	351,588	93,874	49,207	13,307	35,900	67
Shreveport-Bossier City, LA	366,521	85,544	110,918	31,326	79,592	110
Sierra Vista-Douglas, AZ	289,944	67,303	59,293	26,928	32,365	75
Sioux City, IA-NE-SD	426,096	113,482	34,543	4,242	30,301	26
Sioux Falls, SD	303,918	76,517	123,464	52,776	70,688	168
South Bend-Mishawaka, IN-MI	323,581	78,268	119,823	42,820	77,003	175
Spartanburg, SC	263,206	59,944	103,927	50,480	53,447	218
Spokane-Spokane Valley, WA	476,798	111,950	232,486	45,006	187,480	185
Springfield, IL	387,104	109,394	88,674	21,713	66,961	107
Springfield, MA	498,605	130,530	401,606	73,736	327,870	312

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
Springfield, MO	332,335	79,710	215,500	62,305	153,195	236
Springfield, OH	375,992	98,598	51,734	11,468	40,266	64
State College, PA	482,051	115,729	60,331	13,898	46,433	47
Staunton, VA	296,950	66,668	54,579	21,533	33,046	90
Stockton, CA	570,800	130,165	225,285	46,115	179,170	148
Sumter, SC	220,783	51,776	154,141	65,333	88,808	413
Syracuse, NY	367,259	111,228	251,106	55,586	195,520	300
Tallahassee, FL	292,391	70,004	173,212	68,995	104,217	271
Tampa-St. Petersburg-Clearwater, FL	457,593	109,628	1,231,956	265,523	966,433	1,061
Terre Haute, IN	249,180	60,736	90,827	37,253	53,574	178
Texarkana, TX-AR	409,162	105,665	50,542	7,499	43,043	46
The Villages, FL	438,320	102,516	50,332	9,034	41,298	38
Toledo, OH	377,984	100,894	348,462	77,190	271,272	304
Topeka, KS	341,700	91,990	96,118	28,950	67,168	133
Trenton-Princeton, NJ	499,289	147,735	124,666	30,368	94,298	114
Tucson, AZ	526,703	123,022	435,634	58,977	376,657	240
Tulsa, OK	388,462	97,480	404,436	106,909	297,527	512
Tuscaloosa, AL	408,418	90,836	101,401	27,625	73,776	79
Twin Falls, ID	312,462	70,869	38,260	13,027	25,233	82
Tyler, TX	417,977	109,046	82,537	16,941	65,596	89
Urban Honolulu, HI	1,037,948	214,027	342,548	40,564	301,984	143
Utica-Rome, NY	504,421	148,836	125,738	11,972	113,766	47
Valdosta, GA	293,186	72,767	56,723	16,651	40,072	102
Vallejo, CA	583,628	132,015	144,840	41,689	103,151	117
Victoria, TX	415,035	113,414	27,052	6,839	20,213	37
Vineland-Bridgeton, NJ	437,866	133,563	55,553	7,617	47,936	33
Virginia Beach-Norfolk-Newport News, VA-NC	341,084	80,612	741,884	295,044	446,840	1,130
Visalia, CA	450,151	101,632	159,910	34,956	124,954	119
Waco, TX	382,704	103,693	103,766	17,561	86,205	93
Walla Walla, WA	555,347	131,491	21,119	3,292	17,827	13
Warner Robins, GA	324,690	79,578	61,379	21,434	39,945	98
Washington-Arlington-Alexandria, DC-VA-MD-WV	561,240	130,663	2,301,061	953,145	1,347,916	1,822
Waterloo-Cedar Falls, IA	365,773	97,317	63,531	16,051	47,480	76
Watertown-Fort Drum, NY	218,064	58,122	32,397	14,976	17,421	84
Wausau-Weston, WI	322,678	85,477	115,583	38,825	76,758	206
Wausau-Weston, WI	322,678	85,477	115,583	38,825	76,758	206
Weirton-Steubenville, WV-OH	304,703	73,914	45,517	12,174	33,343	68
Wenatchee, WA	459,733	105,208	35,711	8,914	26,797	29
Wheeling, WV-OH	401,218	94,620	67,228	13,084	54,144	62
Wichita, KS	379,695	101,277	241,039	53,028	188,011	282
Wichita Falls, TX	414,824	118,826	63,976	7,769	56,207	66
Williamsport, PA	398,239	103,078	45,622	10,077	35,545	65
Wilmington, NC	450,063	105,218	124,314	27,421	96,893	113
Winchester, VA-WV	380,749	84,516	40,527	15,866	24,661	66
Winston-Salem, NC	343,541	80,290	268,782	79,816	188,966	332
Worcester, MA-CT	451,937	114,678	394,154	122,450	271,704	447
Yakima, WA	444,935	103,927	86,041	13,031	73,010	77
York-Hanover, PA	354,219	95,887	179,966	56,761	123,205	288
Youngstown-Warren-Boardman, OH-PA	379,717	100,388	240,408	53,382	187,026	277
Yuba City, CA	500,426	115,355	65,223	13,420	51,803	64
Yuma, AZ	287,721	66,554	72,591	23,943	48,648	92

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BERNARDO A. BALLESTEROS

March 15, 2022

VIA EMAIL

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
2407 N. Grand River Ave
Lansing, MI 48906

Re: 2021 Michigan Uniform Energy Code; Administrative Rules Part 10

Ladies and Gentlemen:

I am writing on behalf of the Home Builders Association of Michigan concerning the proposed adoption of the residential provisions of the International Energy Conservation Code, 2021 Edition.

The provisions of the governing statute, the Stille-DeRossett-Hale Construction Code Act, MCL 125.1504(3), for energy conservation, direct that the code effectuate specific standards:

> (f) To provide standards and requirements for cost-effective energy efficiency that will be effective April 1, 1997.
>
> (g) Upon periodic review, to continue to seek ever-improving, cost-effective energy efficiencies.
>
> (h) To develop a voluntary consumer information system relating to energy efficiencies.

The term "cost-effective" is defined in section 2a, MCL 125.1502a:

> (p) "Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:

(i) Considers the perspective of a typical first-time home buyer.

(ii) Considers benefits and costs over a 7-year time period.

(iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.

(iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features.

(v) Ensures that the costs of principal, interest, taxes, insurance, and utilities will not be greater after the inclusion of the proposed cost of the additional energy-saving construction features required by the proposed energy efficiency rules than under the provisions of the existing energy efficiency rules.

In other words, for a new code to be adopted, it must be shown to be "cost-effective" as that term is defined in the statute. As published online, the record provided by the Department to date includes only the Request for Rulemaking ("RFR") and a copy of "2021-48 LR Part 10. Michigan Uniform Energy Code (Strike & Bold)," is nothing more than the adoption by reference of the 2021 IECC.

HBAM and its members believe that whether the statutory standards are met is critical to Michigan housing. That information should be provided before further consideration of the adoption of the 2021 IECC.

Very truly yours,

David E. Pierson

DEP/caj

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Mr. Keith Lambert
Director, Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
611 W Ottawa St.
Lansing, MI 48933

March 16th, 2022

Re: Michigan's 2021 Energy Conservation Code Adoption

Dear Director Lambert,

The undersigned organizations write in support of the inclusion of the following effective energy efficiency and electrification provisions in the update of Michigan's commercial and residential energy conservation codes:

1. Maintain the 2021 International Energy Conservation Code (IECC) with no weakening amendments for both commercial and residential codes
2. Require electric vehicle (EV) readiness for both commercial and residential codes
3. Require all-electric residential buildings in climate zones 5 and 6; electric-ready residential buildings in climate zone 7; all-electric commercial buildings in climate zone 5; and electric ready commercial buildings in climate zone 6 and 7.
4. Require increased air monitoring and ventilation for buildings with on-site fossil fuel combustion for commercial and residential codes
5. Require horticultural lighting efficacy for commercial code
6. Require on-site renewables minimum for commercial code

These provisions will lower costs for Michigan residents and businesses; improve indoor air quality and protect public health; increase household resilience from extreme weather events; and significantly reduce climate impacts from the building sector. This is crucial for ensuring Michigan's building codes are equitable, delivering benefits to people facing poor housing quality, high energy burdens, and disproportionate health impacts in their homes and communities resulting from our reliance on fossil fuels.

At a time of global disruption and uncertainty impacting energy prices, the solutions we propose are forward thinking and will improve the state's energy independence and reduce cost-volatility associated with fossil fuels.

In addition, our recommendations would help grow jobs in Michigan. According to the Clean Jobs Midwest report, in 2019, "clean energy jobs grew more than twice as fast as overall employment across the Midwest," with Michigan in particular adding thousands more jobs in renewable energy generation than fossil fuels.[1]

1. Maintain 2021 IECC with No Weakening Amendments for Both Commercial and Residential Codes

We applaud the Bureau for adopting the 2021 IECC residential code in full. As the Bureau moves forward with the code adoption process, we ask that you maintain the full adoption of the 2021 IECC and adopt no amendments that would weaken its efficiency provisions.

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[1] https://www.cleanjobsmidwest.com/state/michigan

As a recent US Department of Energy (DOE) analysis shows, adopting the 2021 IECC is cost-effective and "will provide statewide energy savings of 10.7% across all climate zones compared to the current [Michigan] state energy code. This equates to $327 of annual utility bill savings for the average Michigan household."[2] Much of these savings come from improvements in envelope requirements in the 2021 code such as continuous exterior wall insulation and high air-tightness requirements.

Improved thermal envelopes not only save Michiganders money, but also provide a comfortable and healthy interior environment. An efficient building shell is a key mechanism for improving the comfort of the occupant and meeting the occupant's needs and preferences by reducing unwanted temperature variations. Building envelope improvements are also a key mechanism to protect residents against the extreme weather events we are already experiencing due to climate change.[3] Effective insulation and air sealing can provide essential "hours of safety" during severe weather events and power outages, resulting in critical extra days before the onset of life-threatening conditions from extreme temperatures.[4] This aspect of greater efficiency is called "passive survivability" and provides an important health and safety rationale for stronger energy codes with robust building shell provisions.

One key improvement in building shell efficiency that is included in the 2021 IECC is the requirement to have continuous wall insulation. Requiring continuous insulation benefits homeowners in multiple ways. First, it saves energy versus a cavity only option. More importantly, continuous insulation is an integral part of a holistic approach to insulation which doesn't simply view each section separately, but recognizes that the entire insulation system (walls, floors and ceilings) work together to maximize energy savings. Continuous insulation also provides additional comfort and resilience in the home by eliminating thermal bridges. Thermal bridges are areas of the envelope where cavity insulation doesn't reach (for example, at the studs) which allow heat to flow, which, in turn, undermines the R-value of the walls. Moreover, thermal bridges are areas that are susceptible to moisture. Continuous insulation eliminates this concern. The additional R-5 in the 2021 IECC typically amounts to 1" or less of exterior insulation. At current retail prices of $14/32 sq. ft (contractors should be able to make bulk purchases at a lower cost), this will add no more than $750 to the cost of a home; which is a small price to pay for additional energy savings, increased comfort and reduced risk of moisture.

The efficiency improvements in the 2021 IECC will also help Michigan combate climate change by reducing building sector greenhouse gas emissions. The DOE estimates that adopting the 2021 IECC in Michigan will "reduce statewide CO2 emissions over 30 years by 11,460,000 metric tons, equivalent to the annual CO2 emissions of 2,493,000 cars on the road ."[5]

Unfortunately, the draft commercial code released by LARA removed a key section from the IECC commercial energy conservation code – Section 405.12 to C405.12.5, which requires energy monitoring for buildings over 25,000 square feet. The undersigned organizations and communities strongly oppose this weakening amendment. You can't manage what you don't measure. The ability to understand how much energy your building is using is key to the operation and maintenance of buildings, particularly for large complex buildings that are

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[2] Michigan Residential Code Cost Effectiveness 2021
[3] Extreme weather events have increased significantly in the last 20 years
[4] Hours of Safety in Cold Weather - RMI and https://www.urbangreencouncil.org/babyitscoldinside
[5] IBID US DOE Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan

regulated under the commercial code. Energy monitoring has been shown to reduce energy consumption in buildings by 2 to 8% by giving building owners the information they need to understand how much energy is being used and by what building operations. In addition, a growing number of communities in Michigan are working to achieve carbon neutrality by 2030. For these communities to be successful they must address the energy use of existing buildings which will be much harder without energy monitoring in place.

Given the importance of energy monitoring we recommend Michigan strengthen the monitoring requirement by requiring end use monitoring of EV chargers so operators can better manage both building and vehicle energy consumption.

2. Require EV Readiness for Both Commercial and Residential Codes

The transition to EVs is well underway. The number of EVs on US roads is projected to grow from 1 million vehicles at the end of 2018, to 18.7 million by 2030.[6] Developments in global markets are driving this increase in EV adoption. Michigan's auto manufacturers are working to maintain their leadership in the automotive industry by embracing the transition to EVs. For example, General Motors recently announced it would only produce zero-emission vehicles by 2035.[7] To power this increase in EVs, the U.S. will need 9.6 million charge ports, a substantial portion of which will be installed in single and multi-family residential buildings.[8] Michigan currently only offers 480 publicly accessible charging stations featuring nearly 1,400 charging ports, in addition to 146 private charging stations throughout the state.[9] Without additional EV charging readiness amendments in the state's building code, we miss a key opportunity to help our residents transition to EVs.

A major barrier to the transition to EVs is the lack of charging infrastructure at homes and businesses and the potential need for extensive electrical upgrades to accommodate charging. It is more cost-effective to ensure a building is "EV ready" when it is being built or undergoing major renovations than trying to add equipment after the building is constructed. To reduce expensive retrofit costs, and ensure Michiganders have cost-effective access to charging, Michigan's commercial building code should require a percentage of parking spaces be EV-ready based on the total number of parking spaces and rounded up to the nearest whole number. Michigan's residential building code should incorporate EV-ready provisions that ensure the conduit and infrastructure is in place to support the easy installation of a charger. Approving EV-ready amendments in both the residential and commercial codes will ensure people have affordable access to charging at their homes and workplaces and allow customers to easily transition off of gas-powered vehicles when they are ready and able.

Ensuring buildings have EV chargers or are EV-ready is cost effective. Research undertaken by New Buildings Institute indicates that the cost of the added infrastructure to make a home EV-ready is estimated to be $500 at the time of construction. If a home was not made EV-ready but chose to add an EV charger later with an insufficient supply infrastructure in place, the cost of the retrofit (if the retrofit is feasible) was found to be between $1,500 to $3,000. Therefore, adding the infrastructure to make a home EV-ready saves $1,000 to $2,500 for the average

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[6] EEI celebrates 1 million electric vehicles on US roads
[7] https://www.nytimes.com/2021/01/28/business/gm-zero-emission-vehicles.html
[8] EEI celebrates 1 million electric vehicles on US roads
[9] https://www.michigan.gov/whitmer/0,9309,7-387-90499_90640-558822--,00.html#:~:text=Michigan%20currently%20offers%20480%20publicly,charging%20stations%20throughout%20the%20state.

homeowner who must add an EV charger later. Similar benefits exist for requiring a certain number of EV chargers and EV-ready parking spaces in new commercial and multifamily buildings. These cost benefits are already being realized in Michigan. The City of Ann Arbor, for example, approved an EV-readiness ordinance in January 2021, and the City of Lansing is currently considering adopting a similar ordinance.[10] Similar proposed code changes are being considered in Denver, Colorado, Washington, DC and Wisconsin.

By adding provisions in the energy code to aid the transition from gas-powered to electric-powered vehicles, Michigan will substantially reduce carbon emissions and other harmful pollutants. More accessible EV charging is also necessary for meeting the administration's carbon emission reduction targets and reducing local air pollution. According to the draft MI Healthy Climate Plan, the transportation sector was the second largest source of Michigan's greenhouse gas emissions.[11] EVs can also reduce the health impact of carbon monoxide, nitrogen oxides, and other smog-causing air pollution that is typically released by conventional vehicles.[12] Ensuring affordable access to charging is necessary for making it easier to switch over to EVs and reduce these significant emissions.

Finally, these amendments to the code will help keep Michigan at the forefront of the auto industry and help support our auto workers and the Michigan auto sector as it moves towards a fully electric future.

3. Require All-Electric Residential Buildings in Climate Zones 5 and 6; Electric-Ready Residential Buildings in Climate Zone 7; All-Electric Commercial Buildings in Climate Zone 5, and Electric-Ready Commercial Buildings in Climate Zones 6 and 7.

Further dependence on fossil fuels to heat our buildings and fuel our appliances is a dangerous proposition for Michiganders. It can create volatile utility bills, damage residents' health, and contribute to climate change. Fortunately, improvements in electric heat pump technology allow Michigan to move away from its dependence on fossil fuels in new buildings at little to no cost premium. The residential and commercial building energy codes represent an important opportunity to cost-effectively improve lives. We recommend the Bureau require all-electric residential buildings in climate zone's 5 and 6 and electric-ready buildings in Michigan's coldest climate zone (climate zone 7). The Commission should also require all-electric commercial buildings in climate zone 5 and electric-ready commercial buildings in climate zones 6 and 7. Failure to do so would lock in fossil fuel investments for the future that would be expensive to retrofit. If the Bureau chooses not to require all-electric buildings, the codes should enable greater consumer choice and require electric-readiness in all new Michigan buildings at minimum.

All-electric homes would reduce the volatility of utility bills in Michigan homes and businesses. Compared to last winter, for example, Midwest residents can expect to spend 46% more for gas and 68% more for propane, whereas electricity prices are only expected to rise by about 3%[13]. As the humanitarian crisis unfolds in Ukraine, nations across the world are seeking to insulate themselves from the volatility of fossil fuels, especially Russian gas and oil. On the same day President Biden announced a US ban on Russian oil imports, the executive branch of the

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[10] Lansing could adopt requirement for EV charging stations
[11] Draft MI Healthy Climate Plan
[12] Electric bus fleets are the latest tool improving air quality
[13] EIA 2021 winter fuels outlook

European Union unveiled a plan to slash its dependence on Russian gas[14]. One of the pillars of the European Commission's new REPower EU plan is the increased deployment of electric heat pumps to displace fossil gas demand for heating in Europe. Michigan can join global leaders in insulating its residents from the volatility of fossil fuels by securing energy independence where it is most cost-effective: new construction.

All-electric buildings also significantly improve the health of inhabitants and prevent dangerous consequences of burning fossil fuels such as explosions and carbon monoxide poisonings. On average, Americans spend 90% of their time indoors, meaning indoor air quality has a major impact on our health.[15] The burning ('combustion') of fossil fuels like gas in buildings emits many harmful air pollutants, including nitrogen oxides (NOx), carbon monoxide (CO), and fine particulate matter (PM2.5). Eliminating on-site air pollution in new buildings would reduce early mortality and other health impacts like heart and lung disease. It is especially important to install electric stoves to protect health in new buildings. A comprehensive meta-analysis concluded that children living in homes with a gas stove are 42% more likely to experience asthma symptoms and 24% more likely to be diagnosed with asthma by a doctor compared to those living in homes with electric stoves.[16] The health impacts extend outside the home. Fossil fuel burning buildings emit a range of pollutants that contribute to Michigan's nonattainment of National Ambient Air Quality Standards for ozone and PM2.5. Appliances emit over 10% of all NOx (an ozone and PM2.5 precursor) in the 10 Michigan counties that are either fully or partially in ozone or PM2.5 nonattainment areas.[17]

Today, 20% of Michigan's greenhouse gas emissions are from on-site combustion equipment in residential and commercial buildings.[18] Efficient, all-electric buildings reduce emissions by eliminating on-site fossil fuel combustion in the home and leveraging the state's increasingly renewable electric grid. Electric power emissions in Michigan have fallen by over 30% in the last 15 years, and grid emissions are expected to continue to decrease given Governor Whitmer's Executive Order requiring the state to reach carbon-neutrality by 2050.[19] Michigan's all-electric building stock can leverage the electric grid to ensure that buildings are running off increasingly cleaner, domestically generated electricity.

The benefits of all-electric buildings can be achieved with reductions in upfront costs for new buildings because all-electric homes achieve savings from workers not needing to install gas infrastructure. A study completed by RMI and New Buildings Institute (NBI) demonstrates that across all climate zones in Michigan, building an all-electric 2021 IECC residential code-compliant home reduces upfront costs by more than $6,000. After factoring in the increased upfront cost of efficient electric equipment, the net savings of an all-electric home are over $2,000 compared to a currently code-compliant, gas-powered home. Reducing upfront costs makes homeownership more accessible for Michigan residents by lowering down payments and monthly mortgage bills.

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[14] Russia oil ban: White House announces plan to cut off energy imports - The Washington Post , Joint European action for more affordable, secure energy
[15] Indoor Air Quality | US EPA.
[16] Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children | International Journal of Epidemiology | Oxford Academic
[17] RMI analysis of 2017 National Emissions Inventory (NEI) Data | US EPA.
[18] State Carbon Dioxide Emissions Data - US Energy Information Administration (EIA)
[19] State Carbon Dioxide Emissions Data - US Energy Information Administration (EIA) and Governor Whitmer Announces Bold Action to Protect Public Health and Create Clean Energy Jobs by Making Michigan Carbon-Neutral by 2050

When incorporating operational costs of all-electric homes, the study found that for climate zones 5 and 6, the seven-year lifetime costs are cost-competitive to a gas building (see Appendix one).

The economics across all climate zones in Michigan look even better for customers who would otherwise heat their home with electric resistance or propane technology. Propane fuel is two to three times more expensive than natural gas, making efficient electric appliances like heat pumps an even more attractive option compared to combustion appliances.[20] Studies show that, on average, propane customers would save $564 a year in utility bills and electric resistance customers could save $748 a year if they used high-efficiency, all-electric heat pumps.[21] NBI also completed a cost study which will be released in March that determined moving to an all-electric medium office building reduces construction costs by $2.43 to $2.63 per square foot. These reduced construction costs, resulting from not having to install gas infrastructure in commercial buildings, will no doubt result in positive life cycle cost savings over the lifetime of commercial buildings for building owners in climate zone 5.

For residential buildings, the analysis from RMI and NBI makes clear that an all-electric requirement is cost-effective and well supported in climate zones 5 and 6. In climate zone 7, the extreme cold makes it more challenging for operational costs to remain low for gas customers. For this reason, we recommend ensuring all zone 7 homes are electric-ready, allowing building owners to easily transition to electric appliances when they choose. For commercial buildings, we recommend supporting an all-electric requirement in climate zone 5 and electric-ready construction in climate zones 6 and 7.

4. Require Increased Air Monitoring and Ventilation for Buildings with On-Site Fossil Fuel Combustion Installed for the Commercial and Residential Codes

In zones where the Bureau does not adopt any or all all-electric requirements, we strongly recommend the Bureau include increased air monitoring and ventilation measures.

Buildings that continue to utilize on-site fossil fuel combustion not only release significantly more carbon dioxide than all-electric homes, they can be a hazard to occupant health and safety. Gas leaks can cause explosions; expose people to carbon monoxide, nitrous oxide and PM2.5; contribute to climate change; and waste money. Therefore, the codes should require builders and owners who choose to install gas to receive a third-party inspection to ensure there are no gas leaks and remediate leaks if they are discovered. Buildings with on-site combustion technology should be required to use air quality detection devices to ensure that occupants are made aware of elevated or continuous exposure to emissions that may cause negative health impacts such as asthma, other respiratory issues and cancer. The codes should require the installation of a gas stove range hood with an airflow rate of at least 180 cfm and at least 80% capture efficiency. Furthermore, we recommend the code require balanced ventilation with or without heat or energy recovery. Proper balanced ventilation is key to improving indoor air quality and protecting public health, particularly where gas appliances are used in homes.

Lastly, buildings that continue to use gas and want to use whole air conditioning should be incentivized to select an efficient cold weather climate-certified heat pump to serve both as the A/C and the heat when desired. This incentive can be accomplished in the code by incorporating efficient cold-climate heat pumps as an option to achieve more efficient space

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[20] EIA 2021 winter fuels outlook
[21] Rewiring America MI State Profile electric savings

heating under the prescriptive path. This will help consumers transition to electric heat pumps and allow them to use each application based on their desires and the outdoor temperature, which may impact cost.

5. Require Horticultural Lighting Efficacy in the Commercial Code

The energy demand of horticultural facilities can exceed that of data centers in large part because these facilities have large lighting loads that are approximately 30 to 85 times more than a typical office building. Because sales of both recreational and medical marijuana are now legal in Michigan, it is critical to ensure these facilities are as efficient as possible. We recommend Michigan adopt more stringent lighting efficacy requirements for these facilities (1.9PPE for indoor facilities and 1.7PPE for greenhouses) in order to reduce future unchecked energy demand. The lighting efficacy requirements proposed in Michigan have been adopted for inclusion by the commercial committee in the 2024 IECC because they can both radically reduce energy use of these buildings and are incredibly cost effective.

6. Require On-Site Renewables Minimum in the Commercial Code

In 2020, only 11% of Michigan's electricity is sourced from renewable energy.[22] In order to cost effectively achieve Michigan's goal to be carbon neutral by 2050, Michigan must remove barriers to installing renewable energy on site. According to a recent study from Vibrant Clean Energy, the least-expensive grid involves a large amount of centralized renewables and a large amount of renewables on the building site.[23] Furthermore, many large employers in Michigan have 100% renewable energy commitments.[24] A key component of hitting their goals is the ability to use on-site renewables at their office buildings and facilities. The more we can ensure this generation is already in place at commercial buildings the more attractive Michigan is as a place to locate for these large employers.

It is therefore crucial for new commercial buildings to install a nominal amount of renewable energy on-site during new construction (0.25W/square foot or 5% of the buildings energy use) so that Michigan can reach its carbon neutrality goal in the most cost-effective manner and stay competitive with companies looking to site their next commercial enterprise. Installing renewables on site will also allow building owners to economically benefit from Michigan's transition towards a low-carbon economy and benefit from additional resiliency during disruptions in centrally supplied power.

Thank you for the opportunity to comment on the draft code. We look forward to continuing to work with you to develop a robust building energy code that will cut costs for Michigan residents and deliver public health and climate benefits.

Sincerely,

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[22] EIA Michigan State Profile
[23] Why Local Solar for All Costs Less: A New Roadmap for the Lowest Cost Grid
[24]https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/sep/0930-renewable.html and https://www.steelcase.com/press-releases/steelcase-commitment-to-renewable-energy-equivalent-to-100-of-companys-global-electricity-use/

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Appendix One

Economic Analysis of Proposed Residential Code Amendments

February 2022

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Executive Summary

This analysis examines the cost of adopting the 2021 International Energy Conservation Code (IECC) combined with three additional amendments (all-electric codes, increased air sealing with added mechanical ventilation, and increased wall insulation) compared to the current 2015 Michigan code over a 7-year time period. We completed this analysis in each of Michigan's three Climate Zones (5, 6, and 7) to capture the varying cost impacts across the state. This analysis meets the requirements of the Stille-Derossett-Hale Single State Construction Code Act.[1]

The amendments analyzed in this study are a subsection of the amendments submitted by members of the Michigan Building Decarbonization Coalition. The additional amendments not fully discussed in this analysis include:

- Electric Vehicle-Readiness
- Solar Photovoltaic-Readiness
- Battery Storage-Readiness
- Demand Response Water Heaters
- Electric-Readiness

For more discussion of these additional amendments and how they reduce costs over the lifetime of the building, see Appendix A.

Our results report that single-family detached residential homes built to all-electric 2021 IECC and all-electric 2021 IECC with increased wall insulation and air sealing are cost-neutral over 7 years compared to the current code in Climate Zones 5 and 6. This indicates that these scenarios will not significantly impact costs for Michigan homeowners while immediately improving indoor air quality, increasing comfort and safety, and improving energy efficiency. Over the lifetime of the building, these scenarios will reduce the likelihood of expensive moisture problems, improve outdoor air quality, and reduce climate emissions. This analysis finds that the proposed all-electric code scenarios reduce upfront costs by up to $2,000 in all climate zones because they avoid the costs associated with installation of gas (commonly referred to as natural gas) infrastructure. Additionally, the monthly operational costs and 7-year life cycle costs of the all-electric code scenarios are cost competitive with the current Michigan building code in Climate Zones 5 and 6. This analysis shows that Climate Zone 7 is not cost-effective with an all-electric code requirement, however the cost-effectiveness can be improved with high performance cold climate heat pumps and heat pump friendly electric rate structures which this analysis did not include.

The cost savings persist despite taking a conservative approach to this analysis consistent with the Department of Energy (DOE) building code cost assessment methodology and the Stille-Derossett-Hale requirements. The analysis of the all-electric scenarios used standard efficiency heat pumps that complied with code minimums of the 2021 IECC. However, energy savings can be larger than illustrated in this analysis if buildings use commercially available high-performance cold climate heat pumps. Furthermore, we assume gas prices only increase by inflation to comply with Michigan law, but historically, the volatility of gas prices has significantly exceeded that of electricity prices. Just this winter, gas prices are expected to rise by ~46% compared to last winter in the Midwest, whereas electricity prices are only expected to rise by 3%.[2] Utility bill uncertainty is especially harmful to low-income customers who spend a larger portion

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[1] http://www.legislature.mi.gov/documents/mcl/pdf/mcl-act-230-of-1972.pdf
[2] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf

of their salary on utility costs compared to the average residents in the region[3]. The impact of gas cost volatility is not reflected in this analysis. We also implement standard electric rate designs, but some Michigan utilities provide electric rate structures that better support all-electric buildings and operational savings. For example, the three electric utilities used in this analysis (DTE, Consumers, and UPPCO) have either heating service or time of use rates that could help all-electric homeowners decrease their utility bills. Furthermore, we do not account for the ~30% of consumers using propane in Climate Zone 7.[4] Propane fuel is about two to three times more expensive than natural gas, making electric appliances an even more attractive option compared to combustion appliances.[5] Studies show that on average, propane customers would save $564/year in utility bills if instead they used a high-efficiency all-electric heat pump.[6] Finally, we do not include any rebates for energy efficient appliances which would decrease upfront costs for homeowners. **Because of these conservative assumptions, this analysis could be under reporting the cost effectiveness of the proposed all-electric scenarios.**

After reviewing the results of this analysis, we recommend that all-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation be adopted in Climate Zones 5 and 6. In Climate Zone 7, we recommend that the Construction Codes Commission adopt electric-ready 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation. The proposed scenarios are cost competitive with the current code and deliver necessary health and safety improvements to Michigan homes. Michigan's Construction Code Commission can ensure residents have healthy, safe, and affordable new homes by adopting the proposed amendments.

[3] https://www.aceee.org/sites/default/files/pdfs/u2006.pdf
[4] https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=044e6d58b4f045bf9059cba0a76d059b
[5] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[6] https://map.rewiringamerica.org/states/michigan-mi

Background

This analysis examines the cost of adopting the 2021 IECC with three additional amendments compared to the current 2015 Michigan code. The proposed amendments are as follows:

- **Amendment 1:** Require new residential homes to be all-electric. Homes would be built with efficient, electric appliances like heat pumps, heat pump water heaters, and electric stoves instead of fossil fuel-powered equipment like gas and propane furnaces, hot water heaters, and stoves. Without appliances that combust fossil fuels, homes can reduce indoor air pollution and the corresponding negative impacts on human health, eliminate safety risks related to gas leaks and explosions, and reduce appliance energy use. Furthermore, an all-electric home would not contribute to particulates and ozone that result from combustion in buildings. A 2017 study found that outdoor air pollution from burning fuels in buildings lead to an estimated 841 early deaths in Michigan which corresponds to $9.4 billion in health impact costs for the state.[7] All-electric buildings also reduce greenhouse gas emissions over the lifetime of the building and can reach carbon neutral as the electric grid is increasingly run off renewable energy.
- **Amendment 2:** Improve air sealing requirement from the model 2021 IECC to 2ACH50 and install a heat recovery ventilation or energy recovery ventilation system (also called mechanical ventilation).[8] Increased air sealing reduces air leakage allowing homes to maintain comfortable indoor air temperatures and use their heating and cooling devices less. This reduces energy consumption and increases resilience to extreme weather, as the building can maintain comfortable temperatures for longer during a power interruption. Due to the added tightness of the building from this amendment, this analysis includes mechanical ventilation to comply with the state's mechanical code. Increased air sealing reduces air leakage allowing homes to maintain comfortable indoor air temperatures and use their heating and cooling devices less. They also allow for greater energy efficiency because energy or heat recovery mechanical ventilation can recover energy lost from ventilated air. Mechanical ventilation also circulates fresh outdoor air into the home more often and therefore improves indoor air quality and human health.
- **Amendment 3:** Amend the wall insulation prescription path from R20+5 to R20+7.[9] This would address the moisture issue that arises in Michigan's climate by thickening the exterior insulation. As moist air condenses on cold surfaces within the wall assembly, mold growth that leads to poor indoor air quality and material degradation begins to form. Increased wall insulation in compliance with Amendment 3 would correct this problem.

To assess the impact of the proposed amendments wholistically, this analysis studies three scenarios outlined below. Each scenario is analyzed in each of Michigan's climate zones (5, 6, and 7).

- **Scenario 1- Mixed-Fuel Baseline:** represents a mixed-fuel building built to the current Michigan code, 2015 IECC with the Michigan adopted amendments.[10] This is the baseline scenario for the analysis.

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[7] https://iopscience.iop.org/article/10.1088/1748-9326/abe74c

[8] 2ACH50 is a measure of air sealing in a home and a primary indicator of energy efficiency. 2ACH50 denotes two air changes per hour at 50 Pascals (Pa). A building's ACH50 number indicates how tightly a building was originally constructed and gauges how much air the building leaks.

[9] R20+5 and R20+7 denote the wall insulation values. The R-value is a calculation which measures the flow of heat through an insulation product. The first value (R20) represents cavity insulation. The second value (R5 and R7) represents the continuous insulation.

[10] https://www.michigan.gov/lara/0,4601,7-154-89334_10575_17550-234789--,00.html

- **Scenario 2- 2021 IECC with Amendment 1:** represents a home built to the 2021 IECC code with an amendment that requires the homes to be all-electric.
- **Scenario 3- 2021 IECC with Amendment 1, 2, & 3:** represents a home built to the 2021 IECC code with amendments that requires the home to be all-electric and have increased air sealing and wall insulation with mechanical ventilation. These added amendments are detailed in the background section of this report.

Methods

To evaluate the cost effectiveness of the proposed code scenarios against the current Michigan code approved in 2015, this analysis calculates incremental construction and energy use costs using a standard reference home for Michigan's three climate zones (5, 6, and 7).[11] The standard reference home is the Pacific Northwest National Laboratory's (PNNL) prototype building for new residential construction. Scenarios 2 and 3 are modeled in accordance with the prescriptive compliance requirements of the 2021 IECC Residential Provisions alongside the proposed amendments. The analysis for this study is conducted following the Department of Energy's (DOE) methodology for evaluating cost-effectiveness of residential construction.[12]

To accurately account for local weather and utility rates, we selected a representative city for each climate zone. These cities were selected because they are some of the most populous in the region and are served by one of the major investor-owned utilities (IOU). Table 1 shows the representative cities for each climate zone alongside their respective gas and electric utilities.

Table 1: Representative cities, gas utilities and electric utilities for each Michigan climate zone.

Climate Zone	5	6	7
Cities	Detroit	Traverse City	Houghton
Electric Utility	DTE	Consumers	UPPCO
Gas Utility	DTE	DTE	SEMCO Gas

Using the Building Energy Optimization Tool (BEopt), we model the annual hourly energy use for the standard reference home in all three representative cities and then complete a lifecycle cost analysis (LCCA). BEopt is designed for residential buildings and is based on DOE's whole building energy simulation tool, EnergyPlus. For every residential building, heat transfer equations are implemented based on specific building characteristics such as shape, envelope, internal load, etc. To assess the impact of weather on building energy performance, we use typical meteorological year weather files (TMY3) for each of the representative cities.[13]

For utility costs, we used BEopt to model the utility costs based on energy consumption. Since BEopt analyzes home energy use at an hourly level, we were able to model the current utility rates as opposed to using a state average rate. Using the rates published in each utility's rate book, we were able to appropriately represent fixed and volumetric costs and account for rate differences across seasons and climate zones.

Once the monthly energy and cost impacts were calculated, we used BEopt to complete a 7-year LCCA. The LCCA calculates the total cost of ownership over a specified time period. To do this, BEopt converts

[11] https://www.energycodes.gov/prototype-building-models
[12] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf
[13] https://nsrdb.nrel.gov/about/tmy.html

the cash flows into net present values.[14] Our analysis input assumptions are described in the following section and the results can be found in the results and discussion section.

Input Assumptions

In this section, we outline the assumptions for each scenario including the layout of the standard reference home, technology efficiencies, scenario costs, utility rates, and financial parameters. All other components not listed in the input assumptions section are the same across scenarios. Additionally, the heating and cooling set points are identical across scenarios. Each section details the reference source and an explanation of these assumptions.

1. **Standard Reference Home**: The standard reference home used in this analysis is representative of a single-family detached home in Michigan. As directed by the U.S. DOE, the protype is a single-family two-story home with a roughly 30-ft by 40-ft rectangular shape, 2,376 ft^2 of conditioned floor area excluding the basement. The window area is equal to 15% of the conditioned floor area equally distributed toward the four cardinal directions. The prototype has a heated basement foundation which is the most common foundation in Michigan with 36% of homes having this foundation type.[15] This design is based on the standard reference home used in PNNL's Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan study.
2. **Efficiencies**: For this analysis, the heat pump water heater, gas water heater, and air conditioner technologies have an efficiency that meets minimum code requirements and are sized to meet the needs for the prototype home.[16] We assumed the builder chose to comply with Section R408 (Additional Efficiency Package Options) by installing a gas furnace and air source heat pump with efficiencies listed in Table 2.[17] Note that although we use the minimum required efficiencies, cold weather heat pumps can perform better than the mandated minimum.[18] The Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump database currently contains thousands of tested and rated cold-climate commercial and residential air source heat pump products from dozens of manufacturers, available within the United States, many that have higher efficiency than the heat pump we analyzed.[19] These products are tested and rated to provide heating safely and efficiently down to 5 ºF and below, with minimal impacts to capacity or efficiency that used to occur with older heat pump models. Finally, we modeled an electric stove for the all-electric scenarios (2 and 3) and a gas stove for the mixed-fuel scenario (1). All-electric homeowners can increase stove efficiency and reduce utility costs if they purchase an induction stove which is not included in this analysis.

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[14] The cash flows are defined as the about of cash transfer out of the homeowners account including loan principal, loan interest, replacement costs, utility bills, loan tax deductions, rebates, federal tax credits, non-federal tax credits, and cash payments.
[15] https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf
[16] https://www.energy.gov/eere/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal
[17] https://codes.iccsafe.org/content/IECC2021P1/chapter-4-re-residential-energy-efficiency#IECC2021P1_RE_Ch04_SecR408
[18] https://www.energystar.gov/products/most_efficient/central_air_conditioners_and_air_source_heat_pumps
[19] https://ashp.neep.org/#!/

Table 2: The heat pump water heater, gas water heater, air conditioner, gas furnace, and air source heat pump efficiency values.

Appliance	**Efficiency**[20]
Air Source Heat Pump	SEER 16 and 10 HSPF
Gas Furnace	0.95 AFUE
Heat Pump Water Heater	EF =2.0 and FHR =50 gal/h
Gas Water Heater	EF =0.67 and FHR =67 gal/h
Central Air Conditioner	15.0 SEER and 12.5 EER
Electric Stove	EF=0.4
Gas Stove	EF=0.74

3. **Upfront Costs**: The scenario costs include amendment costs if applicable, the incremental cost of constructing a home to 2021 IECC compared to current Michigan code standards, and infrastructure costs. To estimate these costs, we use commercially available costs on websites like Home Depot and Grainger. We also use values from the RS Means database which estimates construction costs across the United States and is the preferred construction cost database of the National Home Builder's Association.[21, 22]
   a. **Amendment Costs:** The incremental appliance and building material costs for the proposed scenarios are calculated by summing the appliance costs, building materials costs, and the installation labor costs. Specifically, Amendment 1 includes the costs of electric appliances and installation labor costs. The cost of additional electric infrastructure is not included in this value and is provided in the next section. Amendment 2 includes the cost of mechanical ventilation, materials for increased air sealing to 2ACH50, and installation labor. Amendment 3 includes the cost of installation labor and additional continuous insulation for the external walls. All values are representative of the cost for an appliance or material needs that fit the prototype home size in Michigan. More details on how the appliance costs are calculated can be found in Appendix B.

[20] SEER = Seasonal Energy Efficiency Rating
HSPF= Heating Seasonal Performance Factor
AFUE= Annual Fuel Utilization Efficiency
EF= Energy Factor
FHR= First Hour Rating
EER= Energy Efficiency Rating
[21] https://www.rsmeans.com/?gclid=Cj0KCQiAubmPBhCyARIsAJWNpiOxAGeTQv1Uku41s-2-jFDt4P9h4DPMxToRuL2JYb1zCs71HNr8OuIaAspYEALw_wcB
[22] At a meeting of the cost effectiveness subgroup of the commercial committee for the 2024 IECC, a representative of the National Home Builder's Association requested that the cost effectiveness test for the 2024 IECC rely on incremental costs from the RS Means.

Table 3: Incremental costs of appliances and building materials for the proposed amendments in Michigan. Amendment 1 requires new homes to be all-electric. Amendment 2 improves air sealing requirement from the model 2021 IECC to 2ACH50. Amendment 3 amends the wall insulation prescription path from R20+5 to R20+7.

Amendments	**Incremental Appliance and Materials Costs [$/Building]**	**Source**
Amendment 1	$5,831	HVAC Direct, RS Means, Home Depot, Grainger
Amendment 2	$1,710	Supply House, Grainger, RS Means
Amendment 3	$400	Home Depot

b. **Infrastructure Costs:** Collectively called 'gas infrastructure', gas lines, regulators, meters, venting, and wiring components are needed to ensure a home has access to gas for use in its appliances. To safely provide electric power to an all-electric building, homes need increased electric infrastructure over the base code requirements. To do this, homes require a 100A to 200A service upgrade.[23] This analysis includes the costs of gas infrastructure for the mixed-fuel home in Scenario 1 and the incremental electric infrastructure costs for the all-electric home in Scenarios 2 and 3. These costs are summarized in Table 4. It is assumed that the electric and gas infrastructure costs are paid back within the study period. This assumption is made to appropriately characterize the lack of resale value of this infrastructure.[24] See Appendix B for more details about how these costs are calculated and their sources.

Table 4: Incremental upfront costs for installing the gas and electric infrastructure for a home in Michigan.

Infrastructure	Incremental Upfront Cost
Gas Infrastructure	$6,238
Electric Infrastructure	$628

c. **IECC 2015 vs IECC 2021 Construction Costs:** To evaluate the cost difference of the changes introduced by the 2021 IECC without amendments over the current Michigan code, PNNL estimated the incremental construction costs. These methods match the methods used in our analysis and are detailed more specifically in Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan.[25] These are incorporated in the analysis as upfront costs but paid for through the mortgage.

[23] The base cost for 100A electric infrastructure is already included in the base price for the Michigan codes and is therefore not included in the electric infrastructure costs. The electric infrastructure costs only account for the additional cost to go from 100A to 200A electric service.

[24] For equipment that still has life remaining at the end of the analysis period, the resale value of that equipment is included in the last year of the analysis. The resale value (often call the residual value) is based on the percentage of life left in the equipment and the first cost of that piece of equipment. Since the 7-year scenarios have a short analysis period, we have removed the residual value from the costs. This allows us to compare the three scenarios without additional costs that skew the results.

[25] https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf

Table 5: The incremental construction costs between the 2021 IECC without amendments and the current Michigan 2015 IECC.

Climate Zone	5	6	7
2015 IECC vs. 2021 IECC (Heated Basement)	$4,787	$3,780	$5,264

4. **Utility Rates:** This study uses the most recent (as of November 2021) utility rate books to estimate gas and electricity rates for each climate zone's representative utility. Propane rates are not within the scope of this analysis; however, there are a significant amount of propane customers within Michigan. Propane rates are about two to three times higher than natural gas rates indicating that many Michigan residents would see even more cost benefits than this analysis reports. This analysis considers the monthly fixed service charges and volumetric charges for each gas and electric utility. We use utility rate books to estimate gas and electricity rates as opposed to other methods, like state averages, because rate books provide a more accurate representation of the cost dynamics. We selected the standard electric and gas rate structures available from each utility (see Table 6 and Table 7).[26] The standard rate structures do not necessarily present the highest financial savings for the all-electric scenarios. A more detailed evaluation of the existing utility rate structures is needed to determine the optimal rate for an all-electric home. It must be noted that these utility rates are representative of each climate zone and the city, but they are not constant across the climate zone because multiple utilities are operating in each climate zone. In addition to utility rates, interconnection rates are also retrieved.[27] This fee is representative of the one-time fee a gas utility charges to connect the home to the utility's gas infrastructure.

Table 6: The fixed, volumetric, and interconnection charges for the representative gas utilities in Michigan's three climate zones.

	Fixed Charge ($/Month)	**Volumetric Charge** ($/Mcf)	**Interconnection Costs**
SEMCO	12.25	8.6	$200 per meter
Consumers	12.6	8	$200 per meter
DTE	12.25	7.5	$200 per meter

[26] The rate structures used for the utilities in this analysis are as follows:
DTE: RESIDENTIAL SERVICE RATE - RATE SCHEDULE D-1.
Consumers: RESIDENTIAL SUMMER ON-PEAK BASIC RATE RSP.
UPPCO: Residential Heating Service

[27] DTE doesn't list connection fees in their rate book. Since both SEMCO and Consumers have an interconnection fee of $200 per meter, this analysis assumes DTE also has a $200 per meter interconnection fee.

Table 7: The fixed and volumetric charges for the representative electric utilities in Michigan's three climate zones.

Rate Structure	Fixed Charge [$/Mo.]	Volume Rate 1	Volume Charge [$/KW]	Volume Rate 2	Volume Charge [$/KW]	Volume Rate 3	Volume Charge [$/KW]
DTE	7.5	first 17kWh per day	0.0867	Over 17kWh per day	0.1066	N/A	N/A
Consumers	8	Off-Peak[28] between June and Sept	0.10064	On-peak between June and Sept	0.149965	Between Oct and May	0.100496
UPPCO	15	June-September	0.18803	First 500 kWh (October-May)	0.18803	For Excess (Oct.-May)	0.13423

5. **Financial and Economic Parameters:** The financial and economic parameters used in calculating the LCCA are based on the latest DOE cost-effectiveness methodology.[29] These values are retrieved from the PNNL Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan study and used to inform this analysis' LCCA. Most notably, the analysis assumes a 10% down payment which includes appliance costs, gas and electric infrastructure costs, and construction costs. The mortgage is paid over a 30-year period; however, the analysis runs over a 7-year period.

Table 8: The financial and economic parameters used in calculating the LCCA for this analysis.

Down Payment	10% of home price
Mortgage interest rate	5%
Mortgage period	30 years
Marginal income tax rate, federal	15%
Marginal income tax rate, state	4.25%
Analysis period	7 years
Inflation rate	1.60%
Discount rate	5%

[28] *Consumers "On-peak" rate price is active from 2 to 7 p.m.,"Off-peak' rate price 7 p.m. - 2p.m.*
[29] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Results and Discussion

This analysis reports that both all-electric 2021 IECC scenarios in Climate Zones 5 and 6 are cost-competitive over 7 years compared to the current code. Further analysis should explore the cost impact of Scenarios 2 and 3 in Climate Zone 7 if a high-performance cold climate heat pumps and heat pump friendly electric rate structures are used. Additionally, the cost impact for regions serviced by propane or delivered fuel should be further explored since this analysis only assumed natural gas use in the baseline scenario. Climate Zone 7 results are discussed in more detail in Appendix C. Alongside being cost-competitive, Scenarios 2 and 3 provide indoor and outdoor air quality improvements, increased comfort and energy efficiency, and reduced moisture problems. These results provide evidence that all-electric 2021 IECC codes with increase insulation, improved air sealing, and mechanical ventilation will benefit Michigan residents and should be fully considered in this code cycle.

1. Upfront Scenario Costs

The upfront costs for both all-electric scenarios (2 and 3) are more cost-effective than the mixed-fuel scenario (1) in all three climate zones. The upfront costs include the incremental appliance and material costs for each scenario, installation labor, infrastructure costs, and additional costs to comply with the 2021 IECC compared to the current Michigan code. The breakdown of each cost is outlined in the upfront costs section above.

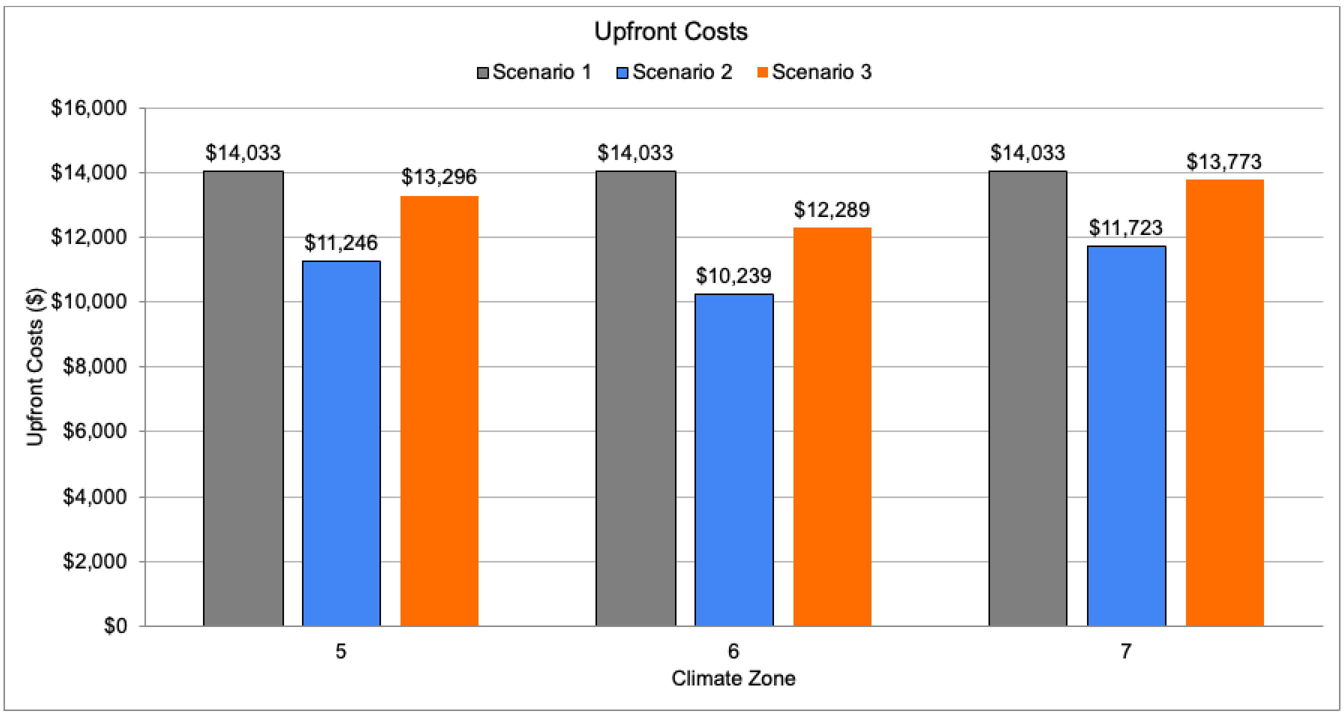

Figure 1: Upfront costs for each scenario. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increased wall insulation, and mechanical ventilation.

Across all climate zones, building an all-electric 2021 IECC code-compliant home (Scenario 2) reduces the upfront costs by 16-27%, delivering over $2,000 in upfront cost savings, compared to Scenario 1. Upfront costs for all-electric 2021 IECC code-compliant homes with increased air sealing, wall insulation, and mechanical ventilation (Scenario 3) are 2-12% less than the current code, delivering over $1,744 in upfront cost savings. In addition to cost benefits, Scenario 3 provides adequate ventilation and moisture prevention benefits.

All-electric homes benefit from cost savings associated with not needing to install the gas infrastructure. Eliminating the need for gas infrastructure costs saves a home more than $6,000 in upfront costs making up for the increased upfront cost of efficient electric equipment. Reducing upfront costs makes homeownership more accessible for Michigan residents. Potential homeowners will have a lower down payment and monthly mortgage payment for the all-electric home versus the mixed fuel home. This is especially advantageous for low or middle-income residents that may find it difficult to pay for a higher down payment or monthly mortgage. These upfront cost savings can be even higher for homeowners who are able to take advantage of rebates for efficient electric appliances provided by electric utilities. Although not included in this analysis UPPCO, DTE, and Consumers each have various rebates for efficient, electric appliances that would further reduce the upfront costs of an all-electric home.[30]

2. **Operational Costs and Energy Use**

Our analysis illustrates that the all-electric scenarios (2 and 3) reduce site energy use in all climate zones and have competitive operational costs compared to the mixed-fuel scenario (1) in Climate Zones 5 and 6. To comply with the law, we use the code mandated minimum efficiency for every appliance.[31]Although this analysis requires the use of code minimum efficiencies, there are many commercially available cold-weather heat pumps with higher performance than the heat pump we modeled. Despite not using highly efficient heat pumps, the all-electric scenarios have significant site energy savings compared to the current code. Figure 2, these homes reduce site energy use by 33 - 41%. These energy savings are the result of the added efficiency of Scenarios 2 and 3 and the use of heat pump technology. Because heat pumps move heat rather than produce it, modern cold weather air source heat pump products see efficiencies 2-3 times higher than electric resistance or gas combustion equipment.[32]

[30] UPPCO's, DTE's, and Consumer's available appliance rebates.
https://ee.uppco.com/Energy-Star
https://www.consumersenergy.com/residential/save-money-and-energy/rebates/heating-and-cooling
https://newlook.dteenergy.com/wps/wcm/connect/dte-web/home/service-request/residential/electric/electric-services/air-source-heat-pump

[31] Code mandate minimum means that the gas furnace and air source heat pumps are compliant with 2021 IECC minimums in section R408. All other appliances are compliant with the federally mandated minimum.

[32] https://ashp.neep.org/#!/

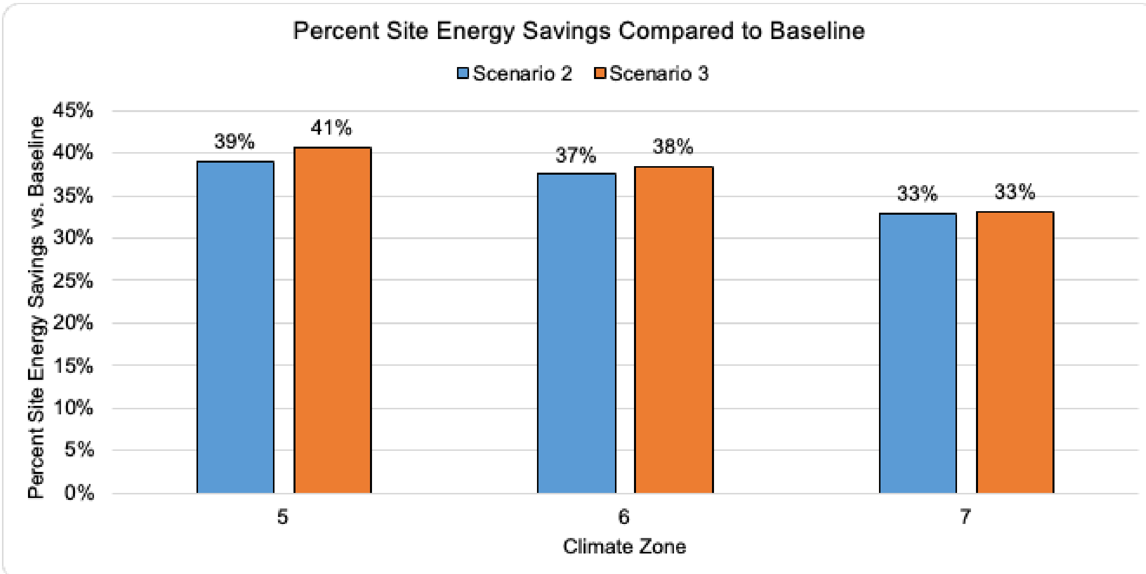

Figure 2: Site energy savings compared to baseline (Scenario 1) for all scenarios in all Climate Zones. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increase wall insulation, and mechanical ventilation.

These energy savings do not directly translate to utility cost savings. As shown in Figure 3, the difference in operational costs is comparable between the mixed-fuel building and the all-electric scenarios in Climate Zones 5 and 6.[33] The operational costs in this analysis include monthly utility bills, mortgage payments, and property taxes. In both climate zones, all scenarios are within $14 a month of each other. Given the source of uncertainty of future energy costs, these results indicate that the operational costs are cost-competitive with each other. The energy savings of the all-electric scenarios could be improved if homes install a more efficient heat pump, or they are enrolled in a utility rate better suited to the energy needs of an all-electric home.

[33] This analysis reports that climate zone 7 would be best suited for high performance cold climate heat pumps. Since the federal law doesn't allow states to specify appliance efficiency, we prioritize the analysis for Climate Zone 5 and 6 in this report and have included discussion of Climate Zone 7 in Appendix C. Although Climate Zone 7 is not cost competitive with the current code, given our conservative assumptions residents with all electric homes can still leverage the additional benefits such as increased indoor and outdoor air quality, reduced moisture problems, and increased energy efficiency and ventilation.

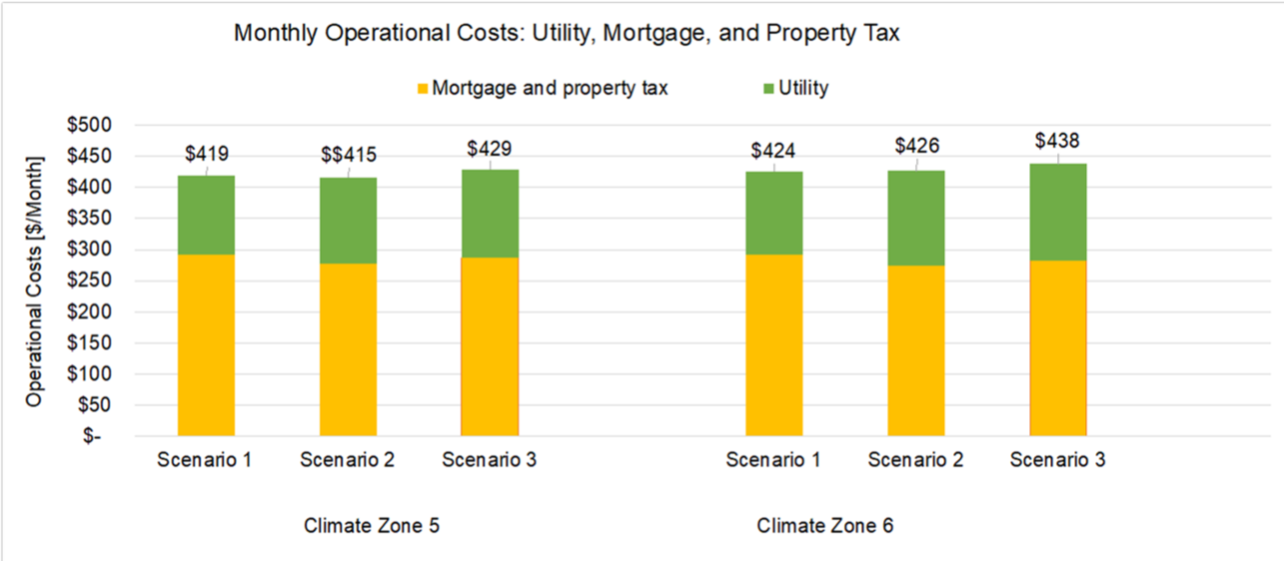

Figure 3: Operational Costs for all scenarios in Climate Zones 5 and 6. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increase wall insulation, and mechanical ventilation.

Although the operational costs are comparable across scenarios, when examining historic retail prices of gas and electricity in Figure 4, we can expect to see less volatility in the all-electric scenarios (Scenarios 2 and 3). This winter, for example, Midwest residential gas expenditures are expected to rise by about 46% whereas electricity prices are only expected to rise by about 3%.[34] Utility bill uncertainty is especially harmful to low-income customers who pay up to 30% of their income on housing costs and can't afford fluctuating utility bills.[35] Overall, this analysis illustrates that the operational costs of all-electric homes are cost competitive with mixed fuel homes. Leveraging efficient heat pumps and beneficial electric rate designs and considering volatile gas prices could make all-electric homes even more competitive. Further discussion of operational costs for Climate Zone 7 can be found in Appendix C.

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[34] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf

[35] https://rmi.org/insight/decarbonizing-homes/

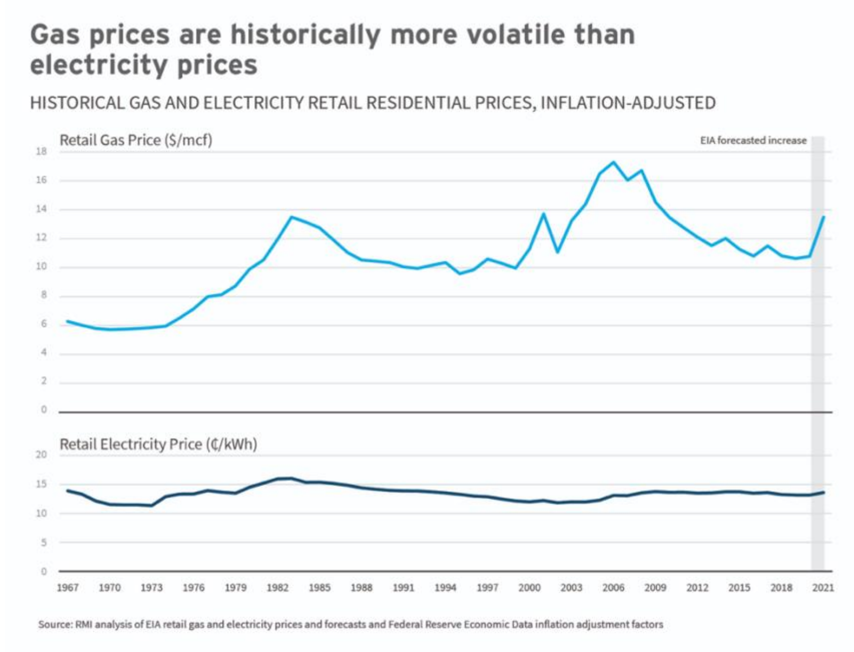

Figure 4: A comparison of U.S. electricity and gas prices since 1967.

3. **7-Year Lifecycle Cost Analysis**

This analysis finds that the lifecycle costs over 7-years for both the all-electric 2021 IECC scenarios (2 and 3) are cost-competitive compared to the mixed-fuel scenario (1) in Climate Zones 5 and 6. The lifecycle costs include the home down payment (10% of the upfront costs) and the monthly operational costs.

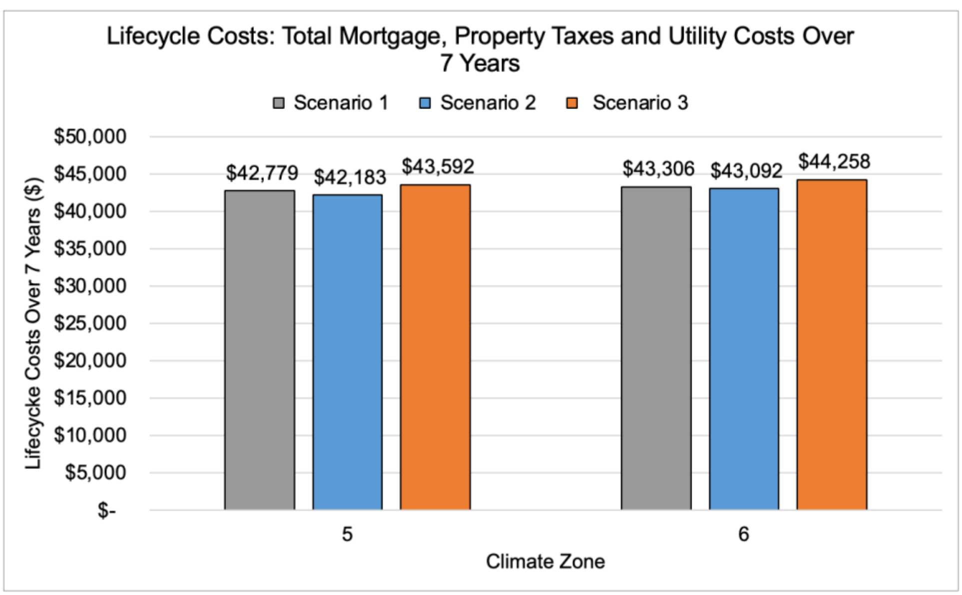

Figure 5: Lifecycle Costs for all scenarios in Climate Zones 5 and 6. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

These results illustrate that Scenario 2, the all-electric home, has the lowest lifecycle costs in Climate Zones 5 and 6. These cost savings range from $600 in Climate Zone 5 to $200 in Climate Zone 6 over the 7-year lifetime of this analysis. Scenario 3 has slightly higher lifecycle costs than the current code, but it is still effectively cost-neutral in Climate Zones 5 and 6 given the expected gas price volatility. These results illustrate that both all-electric scenarios are cost-competitive within 7 years for Climate Zones 5 and 6. Discussion of Climate Zone 7 results can be found in Appendix C. Given the comparable lifecycle costs and the lower upfront costs of the all-electric scenarios, the Michigan Construction Codes Commission should consider the additional benefits that come with the all-electric scenarios.

4. Societal Benefits

As a building's operation and environmental impact is largely determined by upfront decisions, building codes present a unique opportunity to ensure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through retrofits. Early investment in homes through building codes can ensure that Michigan experiences the long-term societal benefits of smart building practices.

a. **Indoor Air Quality:** On average, Americans spend 90% of their time indoors, meaning indoor air quality has a major impact on our health.[36] Amendments 1, 2, and 3 would reduce indoor air pollution within new homes.

- **Amendment 1** would eliminate on-site indoor air pollution caused by the combustion of fossil fuels inside the home by electrifying all appliances. The burning ('combustion') of fossil fuels like gas in buildings emits many harmful air pollutants, including nitrogen oxides (NO_x), carbon monoxide (CO), and fine particulate matter ($PM_{2.5}$). Eliminating on-site air pollution in new buildings would reduce early mortality and other health impacts like heart and lung disease. It is especially important to install electric stoves to protect health in new buildings. A comprehensive meta-analysis concluded that children living in homes with a gas stove are 42% more likely to experience asthma symptoms and 24% more likely to be diagnosed with asthma by a doctor compared to those living in homes with electric stoves.[37] These findings illustrate that electric appliances are necessary to ensure Michigan residents live in healthy new homes.
- **Amendment 2** requires homes to have higher air sealing than what IECC 2021 prescribes and installation of mechanical ventilation. These measures improve indoor air quality by regularly circulating outdoor air into the home. Without proper ventilation, a well-insulated and airtight home will seal harmful pollutants, like carbon monoxide, inside. It is difficult to provide adequate ventilation with unbalanced ventilation strategies such as exhaust fans and uncontrolled air leakage.[38] These unbalanced ventilation strategies often do not supply adequate oxygen supply and can leave excessive humidity and pollutants in the home. Requiring increased air sealing and complementary mechanical ventilation system in Amendment 2 will ensure Michigan residents will have clean, healthy ventilated air.

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[36] https://www.epa.gov/report-environment/indoor-air-quality#:~:text=Americans%2C%20on%20average%2C%20spend%20approximately,higher%20than%20typical%20outdoor%20concentrations.
[37] https://academic.oup.com/ije/article/42/6/1724/737113?login=false
[38] https://rmi.org/airtightness-buildings-dont-let-slip-cracks/

- **Amendment 3** improves energy efficiency and reduces moisture and mold with increased wall insulation. By protecting the home from mold before it can grow, new homes with improved wall insulation can stop mold-related health impacts from ever occurring.

Adopting all-electric building codes with increased air sealing and mechanical ventilation will drastically improve indoor air quality and protect public health while also keeping energy costs low and the home comfortable.

b. Outdoor Air Quality: Direct emissions from buildings also impacts the outdoor air quality of local communities. Mixed-fuel buildings emit a range of pollutants that contribute to Michigan's nonattainment of National Ambient Air Quality Standards for ozone and $PM_{2.5}$. Appliances emit over 10% of all NOx (an ozone and $PM_{2.5}$ precursor) in the 10 Michigan counties that are either fully or partially in ozone or $PM_{2.5}$ nonattainment areas.[39] Ground-level ozone and particulate matter are also linked to short- and long-term health impacts such as asthma, pulmonary disease, or premature death and environmental impacts that negatively impact agriculture and vegetation.[40,41] Eliminating on-site emissions through appliance electrification and energy efficiency measures reduces health harming outdoor air pollution.

c. Greenhouse Gas Emissions: This analysis reports that building efficient, all-electric new homes in Michigan will reduce the state's climate impacts. Today, 20% of Michigan's greenhouse gas emissions are from on-site combustion equipment in residential and commercial buildings.[42] Efficient, all-electric buildings reduce emissions by eliminating on-site fossil fuel combustion in the home and leveraging the state's increasingly renewable electric grid. Electric power emissions in Michigan have fallen by over 30% in the last 15 years, and grid emissions are expected to continue to decrease given Governor Whitmer's executive order requiring the state to reach carbon-neutral by 2050.[43,44] Michigan's all-electric building stock can leverage the electric grid to ensure their buildings are running off increasingly cleaner electricity. To account for the uncertainty of the pace of renewable energy in Michigan, we used two future scenarios from the National Renewable Energy Laboratory (NREL)[45] to illustrate the possible range of emissions reductions:

  - **Ambitious emission reduction:** Michigan's electric power sector reduces emissions 95% by 2035. This emission scenario would meet Governor Whitmer's climate goals early.
  - **Conservative emission reduction:** Michigan's electric power sector reduces emissions 95% by 2050. This emission scenario assumes coal is online until 2044 and would not meet Governor Whitmer's climate goals.

This analysis illustrates that the all-electric scenarios (2 and 3) are emissions savings compared to the gas alternative (Scenario 1) in both an ambitious and conservative emission reduction future.

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[39] RMI analysis of EPA 2017 National Emissions Inventory data, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data#dataq.
[40] https://iopscience.iop.org/article/10.1088/1748-9326/abe74c
[41] https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#:~:text=What%20are%20the%20environmental%20effects,vegetation%20during%20the%20growing%20season.
[42] https://www.eia.gov/environment/emissions/state/
[43] https://www.eia.gov/environment/emissions/state/
[44] https://www.michigan.gov/whitmer/0,9309,7-387-90499_90640-540289--,00.html
[45] https://www.nrel.gov/analysis/standard-scenarios.html

The more quickly emissions fall from the electricity sector, the larger the emissions savings from the all-electric scenarios. Under the ambitious renewable adoption case, the all-electric scenarios reduce emissions by 10% to 20% within the 15-year lifetime of the appliance compared to the current code. These emissions savings will continue to grow throughout the lifetime of the home. By 2050, when Governor Whitmer has ordered the state's economy to be carbon-neutral, emissions savings for an all-electric home built in 2022 can grow to 33%. Figure 6 shows the cumulative emissions until 2050 of a home built in 2022 for each scenario. All-electric homes can achieve a near complete reduction in the building's operational emissions if they provide their home's electricity needs fully with renewable energy. This rate of reduction is not possible with homes that combust fossil fuels to meet part of the home's energy needs.

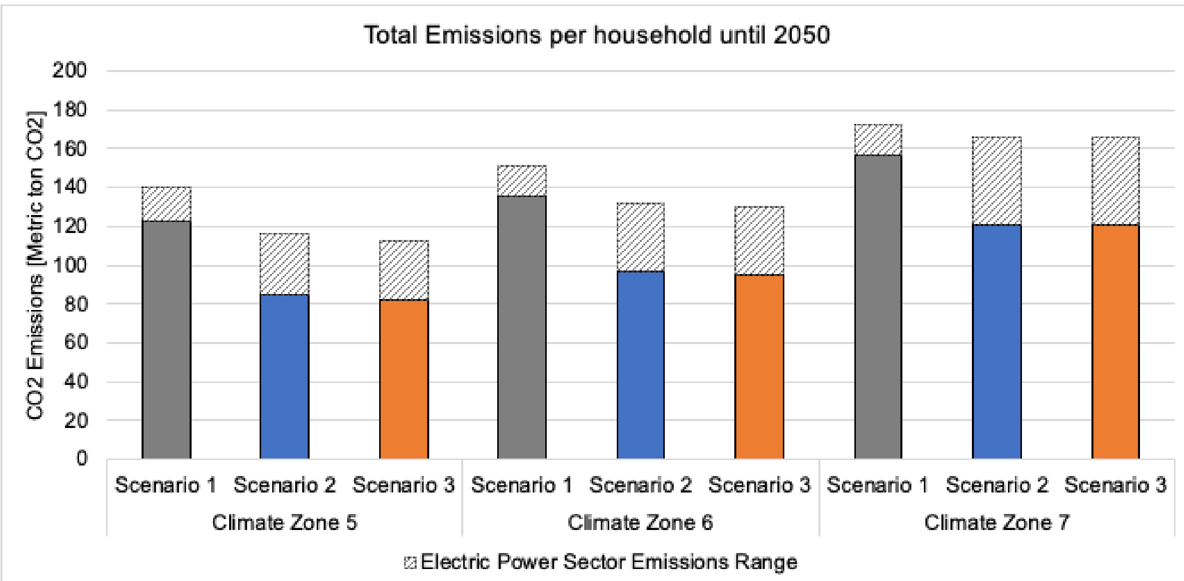

Figure 6: CO_2 emissions per household until 2050 assuming ambitious and conservative electric power emissions. The gray, hatched bars represent the possible emissions range depending on the rate of electric power decarbonization. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

d. **Reduced Moisture Problems:** In the residential chapter of the 2021 IECC, the wall insulation requirement for Climate Zones 5 and 6 includes the option to use R20 +5 ci. This insulation requires R-20 for cavity insulation along with R-5 for exterior continuous insulation. Unfortunately, this type of insulation assembly may pose moisture problems in Michigan's climate zones. Condensation within the wall assembly is a significant issue in cold climates. As warm, moisture-laden air moves through a wall assembly, it condenses on cold surfaces like exterior sheathing. This liquid moisture facilitates pathogen growth that leads to poor indoor air quality and material degradation. As vapor barriers in wall assemblies are rarely perfect, one recommended strategy (such as by the US Office of Efficiency and Renewable Energy) is to add continuous insulation on the outside of the building sheathing to eliminate condensation. Research shows that the exterior insulation R-value should be, at a minimum, roughly 35% of the cavity insulation.[46] In the case of R20 + 5, the exterior insulation is 25% meaning there is insufficient exterior insulation to protect against cold-weather condensation in the walls. To avoid this problem, Amendment 3 proposes to change the prescriptive R20 + 5ci requirement to R20 + 7ci. The additional exterior insulation would protect against cold-weather condensation and potential moisture-related problems.

e. **Resilience:** An efficient building-shell is a key mechanism for improving the comfort in a building by providing greater control for the occupant and reducing unwanted temperature variations. Building envelope improvements are also a key mechanism to protect building occupants against the extreme weather events we are already experiencing due to climate change. Effective insulation and air sealing can provide essential "hours of safety" during severe weather events and power outages, resulting in critical extra days before the onset of life-threatening conditions from extreme temperatures.[47] [48] This benefit of greater efficiency is called "passive survivability" and provides an important health and safety rationale for stronger energy codes. Upgrading Michigan's building codes to 2021 IECC with Amendments 2 and 3 will increase the resiliency of new Michigan homes and improve the safety for residents.

[46] https://www.buildingscience.com/documents/digests/bsd-controlling-cold-weather-condensation-using-insulation

[47] https://rmi.org/insight/hours-of-safety-in-cold-weather/

[48] https://www.urbangreencouncil.org/babyitscoldinside

Conclusion

This analysis studies the cost and energy use impacts of three scenarios in Michigan's three climate zones for a 7-year analysis period.

1. **Scenario 1- Mixed-Fuel Baseline:** represents a mixed-fuel building built to the current Michigan code, 2015 IECC with the Michigan adopted amendments.[7] This is the baseline scenario for the analysis.
2. **Scenario 2- 2021 IECC with Amendment 1:** represents a home built to the 2021 IECC code with an amendment that requires the homes to be all-electric.
3. **Scenario 3- 2021 IECC with Amendment 1, 2, & 3:** represents a home built to the 2021 IECC code with amendments that requires the home to be all-electric and have increased air sealing and wall insulation with mechanical ventilation.

The 7-year cost analysis was completed in service of the Stille-Derossett-Hale Single State Construction Code law which requires the Construction Codes Commission to consider the costs and benefits of any new code proposal over a 7-year period.[49] In addition to the scenarios analyzed in this report, members of the Michigan Building Decarbonization Coalition submitted additional amendments to the residential code (see Table 9). These amendments would allow Michigan residents to install climate aligned technology when they are able while ensuring the future retrofit is not cost prohibitive. More discussion of the readiness amendments is available in Appendix A.

Table 9: A list of additional readiness amendments with a description and states that are considering these amendments.

Additional Amendments	Description	Cost Savings to Install During Instead of After Construction	Jurisdictions Considering Amendments
All-Electric Readiness	Install electric infrastructure needed to install all-electric appliances	Up to $6,000	Wisconsin, Washington State, Denver, CO, Washington, DC, New York State, Massachusetts, Connecticut and California
EV-Readiness	Install electric infrastructure needed to install an EV charger	$1,000-$2,500	Ann Arbor, Michigan, Denver, Colorado, Washington, DC and Wisconsin
Solar PV-Readiness	Install electric infrastructure needed to install solar PV.	$4,000	Washington, DC, and it has been adopted in Vermont and Massachusetts.
Demand Response Water Heaters	Require demand response water heaters.	$180/year	California, Oregon, and Washington have passed it. Wisconsin is considering
Battery Storage-Readiness	Install electric infrastructure needed to install battery storage	More Research Required	More Research Required

[49] http://www.legislature.mi.gov/documents/mcl/pdf/mcl-act-230-of-1972.pdf

The results of this analysis indicate that the Michigan Construction Codes Commission should adopt the following residential building codes:

- **All-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zones 5 and 6.**
- **Electric-Ready 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zone 7.**

All-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation (Scenario 3) has minimal impact on the monthly and overall costs of new buildings in Climate zones 5 and 6 while delivering important benefits to residents like improved indoor air quality, reduced negative health outcomes, more resilient and safe homes, and reduced moisture problems Since all-electric codes are not explicitly cost-effective in Climate Zone 7, the Construction Code Commission should adopts electric-ready codes in this region. This will keep costs down while future proofing these homes and enabling an affordable transition to electric appliances in the future. Additional consideration should be given to customers that would normally be served by propane in Climate Zone 7. Although outside the scope of this analysis, propane prices are two to three times more expensive than the natural gas prices used in Scenario 1 suggesting that current propane customers could see even greater utility bill savings than reported in this analysis.

In conclusion, the Michigan Construction Codes Commission should adopt all-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zones 5 and 6 to ensure Michigan begins building healthy, climate-aligned homes in 2023. The proposed code amendments will improve indoor and outdoor air quality which will have positive health impacts for residents of Michigan. The proposed amendments will also ensure the home is highly energy efficient and reduce problematic moisture issues that are especially prevalent in the cold climate of Michigan and expensive to repair. Finally, the proposed code scenarios remain cost-neutral against the current code while reducing emissions and ensuring the state aligns with Governor Whitmer's climate objectives. The Construction Codes Commission has a clear pathway to make Michigan a leader in climate change and healthy buildings while ensuring that owning a home in Michigan remains affordable for all.

Appendix A: Other Amendments

In order to meet Governor Whitmer's 2050 carbon neutrality goal, Michigan must transition away from combustion equipment in buildings and install electric appliances powered by renewable electricity. New buildings also need to be EV-ready to meet Michigan's growing demand for electric vehicles. Finally, the state's building must be grid interactive and battery storage-ready to balance electricity demand. The following amendments will allow Michigan to implement smart construction practices that support climate-aligned technology without being cost-prohibitive.

1. **Electric Readiness:** As we have detailed throughout this report, all-electric new construction is cost-competitive when compared to building a mixed-fuel home in Climate Zones 5 and 6. Climate Zone 7 is not found to be cost-competitive with the equipment and rates modeled. Electric readiness can serve as a bridge for Climate Zone 7 residents to switch to all-electric appliances when the costs are competitive. Electric readiness requires new homes to install the infrastructure needed to accommodate all-electric appliances so that it is easy and affordable to switch. Electric Readiness should be adopted in Climate Zone 7 because it allows residents to have the option to affordably retrofit their home when they are ready without leaving residents with cost-prohibitive retrofits later. **Research completed by NBI and partners using RSMeans finds that retrofitting a home later can cost up to $6,000 whereas installing electric ready infrastructure at the time of construction costs about $600.** To reduce expensive retrofit costs, it is therefore critical that Michigan's building codes require electric-ready infrastructure. Similar amendments are being explored in Wisconsin, Washington State, Denver, CO, Ann Arbor, MI, Washington, DC, New York State, Massachusetts, Connecticut and California.
2. **Electric Vehicle Readiness:** The widescale adoption of electric vehicles (EVs) is a key climate strategy to reduce GHG emissions from Michigan's transportation sector. Fortunately, the transition to electric vehicles (EVs) is already underway and auto manufacturers in Michigan are embracing this change, especially General Motors who recently announced it would only manufacture electric vehicles by 2035.[50] The number of EVs on U.S. roads is projected to grow from one million vehicles at the end of 2018, to 18.7 million by 2030.[51] To charge these new EVs, the U.S. will need 9.6 million charge ports, a substantial portion of which will be installed in single and multi-family residential buildings.[52] A major barrier to the transition to EVs is the lack of charging infrastructure at homes and businesses and the potential need for extensive electrical upgrades. It is more cost-effective to ensure a building is "EV ready" when it is being built or undergoing major renovations than trying to add equipment after the building is constructed. To reduce expensive retrofit costs, it is therefore critical that Michigan's building codes require parking spaces to be EV-ready. The City of Ann Arbor approved an EV-readiness ordinance in January 2021 and similar proposed code changes are being considered in Denver, Colorado, Washington, DC and Wisconsin.

   By adding provisions in the energy code to aid the transition from gas-powered to electric-powered vehicles, Michigan will not only reduce carbon emissions in the state substantially but will also reduce other pollutants. Vehicle emissions are the largest source of carbon monoxide, nitrogen oxides, and other smog-causing air pollution in cities. Research currently undertaken by NBI and

[50] https://www.nytimes.com/2021/01/28/business/gm-zero-emission-vehicles.html

[51]https://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/EEI%20Celebrates%201%20Million%20Electric%20Vehicles%20on%20U-S-%20Roads.aspx

[52]https://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/EEI%20Celebrates%201%20Million%20Electric%20Vehicles%20on%20U-S-%20Roads.aspx

partners indicate that the cost of the added infrastructure to make a home EV-ready is estimated to be $500 at the time of construction. If a home was not made EV-ready but chose to add an EV charger later with an insufficient supply infrastructure in place, the cost of the retrofit (if the retrofit is feasible) was found to be between $1,500 to $3,000. **Therefore, adding the infrastructure to make a home EV-ready saves $1,000 to $2,500 for the average homeowner who must add an EV charger later.**

3. **Solar PV Readiness:** It is more cost-effective to ensure a building is "solar ready" when it is being built or undergoing major renovations than trying to add equipment after the building is constructed. If a building is not built to be "solar ready," it can be technically infeasible or economically prohibitive to install solar later. Therefore, it is crucial to remove this barrier in new residential buildings so that homeowners can install renewable energy on-site to enable a low-cost carbon free grid. This amendment would require all new homes in Michigan to be solar ready by requiring a designated 300 square foot minimum "solar ready zone" on the roof. Conduit and wire from this zone must be installed and space in the electrical panel must be reserved for a future solar array. Homes where solar is not feasible due to shading or not enough solar exposure due to orientation are exempt. Recent analysis by NBI and partners using cost data from RS Means indicates that adding the infrastructure to make a home solar ready would cost $435 or $0.17 per square foot for a typical home at the time of construction. According to an NREL report, if a home is not made solar ready but chooses to add solar later, the cost of the retrofit (if the retrofit is feasible) is $4,373 or $1.75 per square foot. **Therefore, adding the infrastructure to make a home solar ready saves about $3,938 or $1.58 per square foot for homeowners who choose to add solar later.** The proposed change is in Appendix RB Solar-Ready provisions of the 2021 IECC and is being considered in Washington, DC, and previous versions have been adopted in Vermont and Massachusetts.
4. **Battery Storage Readiness:** Energy storage will soon become critical to aid in this transition by storing energy to match grid demands. Energy storage is expected to grow by over 40% each year until 2025[53], and Michigan, because of its manufacturing background and experience in batter-storage technology for cars, is becoming a clear leader in this market. These systems could also improve Michigan's economy, present a cost savings opportunity for Michigan homeowners in the future, and increase Michigan's resilience to power outages. Incremental costs of ensuring buildings are energy storage ready will increase costs but those costs are minor compared to retrofit costs for buildings who choose to add storage later when a building is not storage ready. These incremental cost impacts include additional design professional fees, markings on the panels, and additional construction costs only if there were not spare square footage available in the equipment or storage rooms where panels are generally located. In that case, it would be equal to the construction costs for an additional 8 square feet of storage space.
5. **Demand Response Water Heaters**: As Michigan increases the amount of electricity generated from renewables to meet the state's carbon neutrality goals, buildings must be prepared to aid in this transition by reducing energy use to match grid demands. Demand response controls for water heating and space conditioning are an inexpensive and proven technology that adds this needed functionality to buildings. In addition, demand responsive functionality will present a cost-saving opportunity for buildings in the future. Demand response requirements for electric storage water

[53] https://www.irena.org/newsroom/articles/2020/Mar/Battery-storage-paves-way-for-a-renewable-powered-future#:~:text=Globally%2C%20energy%20storage%20deployment%20in,40%25%20each%20year%20until%202025.&text=Currently%2C%20utility%2Dscale%20stationary%20batteries,%2C%20complementing%20utility%2Dscale%20applications.

heaters based on ANSI/CTA-2045-B will standardize the socket, and communications protocol, for heat pump water heaters so they can communicate with the grid and demand response signal providers. Demand responsive thermostats were found to be extremely cost effective in 2011. Every dollar spent on a demand response thermostat yielded between $2 to $3 in monthly operating cost savings over a 15-year period.[54] In the 10 years since, equipment prices have decreased (less than $60 for a basic DR thermostat compared to just under $30 for a basic 7-day programmable thermostat). Demand response controls for water heaters, which costs about $170, become cost effective when enrolled in a demand response program. Armada Power customers in Ohio who enrolled their water heaters in a demand response program saved $184 annually by enrolling in the program. **If Michigan utilities institute a similar program to shape demand, a customer would reap $12 in energy cost savings for every $1 spent on the additional controls.** Versions of this standard are included in codes or other requirements in California, Oregon, and Washington, and under consideration in several other states including Wisconsin.

6. **Battery Storage Readiness:** As Michigan increases the amount of electricity generated from renewables, buildings must be prepared to aid in this transition by storing energy to match grid demands. Energy storage is expected to grow by over 40% each year until 2025[55], and Michigan, because of its manufacturing background and experience in batter-storage technology for cars, is becoming a clear leader in this market. These systems could also improve Michigan's economy, present a cost savings opportunity for Michigan homeowners in the future, and increase Michigan's resilience to power outages. Incremental costs of ensuring buildings are energy storage ready will increase costs but those costs are minor compared to retrofit costs for buildings who choose to add storage later when a building is not storage ready. These incremental cost impacts include additional design professional fees, markings on the panels, and additional construction costs only if there were not spare square footage available in the equipment or storage rooms where panels are generally located. In that case, it would be equal to the construction costs for an additional 8 square feet of storage space.

Appendix B: Scenario Costs

1. **Appliance Costs:** The total appliance costs for the proposed building code scenarios are calculated by summing the appliance costs and the installation labor costs. The cost of the appliance, estimate

[54] https://info.aee.net/peak-demand-reduction-report

[55] https://www.irena.org/newsroom/articles/2020/Mar/Battery-storage-paves-way-for-a-renewable-powered-future#:~:text=Globally%2C%20energy%20storage%20deployment%20in,40%25%20each%20year%20until%202025.&text=Currently%2C%20utility%2Dscale%20stationary%20batteries,%2C%20complementing%20utility%2Dscale%20applications.

labor costs, and total costs are listed Table 10 alongside the source of our cost estimates. Space conditioning equipment is sized based on the prototype and local weather files. All other appliances are standard size regardless of climate zone. Labor costs are estimated at $115/hour as an assumed average cost for Michigan's HVAC services.[56]

Table 10: Upfront costs for appliance costs in Michigan.

Appliance	Appliance Cost	Labor Hours	Labor Cost	Total Cost	Source
Air Source Heat Pump	$2,331	4	$460	$2,791	RS Means[57]
Gas Furnace	$1,119	5	$575	$1,694	HVAC Direct, RS Means
Gas Water Heater	$957	4	$460	$1,417	Home Depot, RS Means
Heat Pump Water Heater	$1,013	7	$747	$1,760	Home Depot, RS Means
Electric Stove	$935	3	$345	$1,280	Home Depot, RS Means
Gas Stove	$829	3	$345	$1,174	Home Depot, RS Means
AC	$2,078	7	$805	$2,883	Grainger, RS Means

2. **Air Sealing and Wall Insulation Costs:** Amendments 2 and 3, included in Scenario 3, require higher air sealing, mechanical ventilation, and more wall insulation to reduce moisture issues and improve household efficiency. Amendment 2 requires mechanical ventilation to ensure there are enough air changes within the home to maintain high air quality due to the lower air leakage. The mechanical ventilation system and additional air sealing materials costs about $1,250. Coupled with four hours of installation labor leads to a total cost of $1,710 for the entire amendment. Amendment 3 costs $400 for labor and building materials. The difference between 1" of exterior insulation (R-5) and 1.5" (R-7.5) is about $7 per board (which is equivalent to 32 square feet). For a typical home, with roughly 1,800 square feet of wall area, the additional cost is about $400 per home. The costs to repair moisture problems in walls far outweigh the $400 needed to prevent moisture issues.

3. **Infrastructure Costs:**
    a. Scenario 1: The mixed fuel scenario in our analysis includes the upfront gas infrastructure cost. Gas infrastructure includes the gas line, regulator, gas meter, gas venting, and wiring components needed to ensure a home has access to gas. These do not include gas line extension costs which utilities charge new customers to extend gas lines to meet a new home. This value is excluded because we were not able to get an accurate estimate. Without

[56] https://www.rsmeans.com/?gclid=Cj0KCQiAubmPBhCyARIsAJWNpiOxAGeTQv1Uku41s-2-jFDt4P9h4DPMxToRuL2JYb1zCs71HNr8OuIaAspYEALw_wcB
[57] https://www.rsmeans.com/
RS Means is a database that estimates the costs of construction codes.

this value, the costs associated with Scenario 1 underestimates the real upfront costs that should be applied under the current Michigan code.

b. All-Electric Scenarios 2 and 3: The all-electric scenarios include additional electrical infrastructure costs that are not included in the mixed fuel scenario. This electric infrastructure includes additional wiring and equipment costs to ensure an all-electric home can safely provide electric power to all appliances. The additional cost in this study includes the incremental cost of upgrading a home to have 200A electric service instead of 100A electric service.

The sources for both gas and electric infrastructure alongside a breakdown of the costs are presented in Table 11.

Table 11: Upfront costs for infrastructure in Michigan.

	Infrastructure Component	**Component Cost**	**Labor Hours**	**Labor Cost**	**Total Cost**	**Source**
Gas Infrastructure	Gas Line	$2,440.94	8	$920.00	$3,360.94	Grainger[58], RS Means
	Gas Regulator	$53.06	0.5	$57.50	$110.56	Grainger, RS Means
	Gas Meter	$1,952.76	2.5	$287.50	$2,240.26	Grainger, RS Means
	Gas Venting	$212.26	1.25	$143.75	$356.01	Grainger, RS Means
	Wiring	$64.56	1	$115.00	$179.56	Grainger, RS Means
Electric Infrastructure	Incremental cost of 100A to 200A Service Upgrade	$628	0	0	$628.00	Grainger

[58]RS Means database estimates construction costs across the United States. Grainger is an industrial supplies company that sells equipment products across the US.

Appendix C: Climate Zone 7 Results

To comply with code minimums, this analysis used the minimum efficiency code compliant appliances. As discussed throughout this report, heat pumps are valuable for their high efficiency ratings and energy savings. Since we did not use the most efficient appliances commercially available, the all-electric scenarios did not realize their maximum energy or cost savings potential. Due to northern Michigan's high electricity prices and very cold climate, Climate Zone 7 is best suited for high performance cold climate heat pumps and all-electric friendly rate structures. However, the narrow analysis required by the Stille-Derossett-Hale Single State Construction Code Act does not show that Scenarios 2 and 3 are cost-effective in Climate Zone 7. Although we choose to prioritize Climate Zones 5 and 6 throughout this report, we have outlined the results for Climate Zone 7 in this appendix. To fully understand the economics of electrification in Climate Zone 7, a further analysis on higher performing heat pumps, optimized rate studies, and the impacts on non-gas customers should be conducted. Fuel type is an especially important sensitivity to consider since Climate Zone 7 coincides with areas where there is a lot of electric resistance and propane usage.[59] For this customer class, studies show that cold weather heat pumps produce significant cost savings to customers.[60] Due to resource constraints, this analysis did not fully explore the cost savings associated with an efficient heat pump for customers who would have otherwise heated their home with electric resistance or propane.

1. **Upfront Costs:** The upfront cost for Climate Zone 7 was previously outlined in the results section. As shown in Figure 7, **the all-electric scenarios (2 and 3) have lower upfront costs than the current Michigan code.** An all-electric 2021 IECC code with insulation and air sealing amendments reduces costs by over $200. The all-electric 2021 IECC code reduces costs by over $2,000.

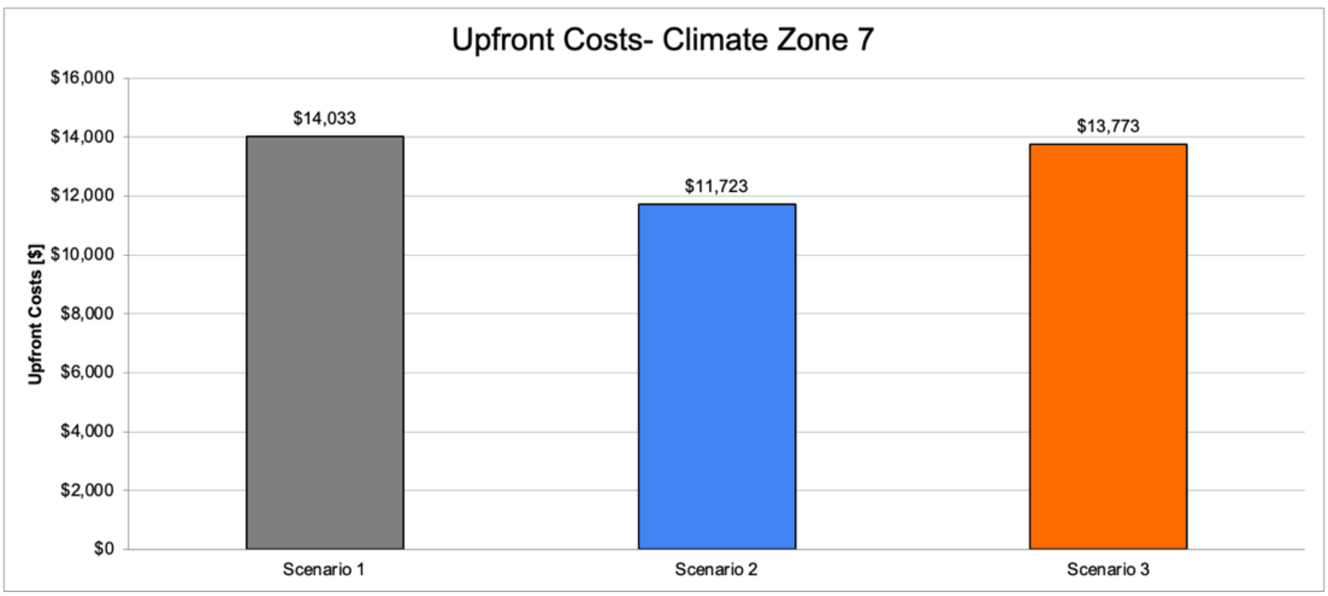

Figure 7: Upfront costs for each scenario in Climate Zone 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

[59] https://www.michigan.gov/mpsc/consumer/petroleum
[60] https://map.rewiringamerica.org/states/michigan-mi

The upfront costs for the mixed fuel home are more than the all-electric homes in Climate Zone 7 because of gas infrastructure costs. To install the equipment needed to deliver natural gas to the home, homeowners pay over $6,000 upfront. Additionally, many upper Michigan utilities (like UPPCO and WE Energies) have rebates for efficient electric appliances that would reduce these upfront costs even more.

2. **Operational Costs:** The operational costs in this analysis include monthly utility bills, mortgage payments, and property taxes. As shown in Figure 8, **the all-electric scenarios (2 and 3) have higher operational costs than the current Michigan code in Climate Zone 7 , but this can be improved with higher efficiency heat pumps and optimized electric rate structures.** An all-electric 2021 IECC code with insulation and air sealing amendments increases monthly costs by $83. The all-electric 2021 IECC code increased operational costs by over $74 per month.

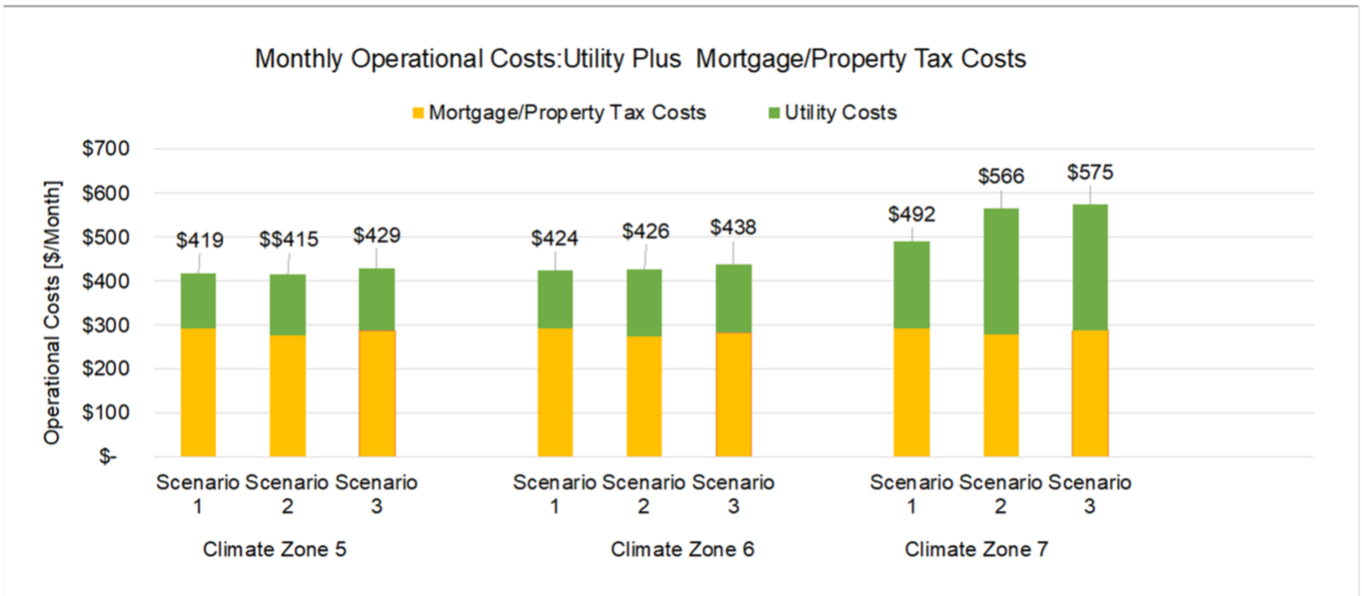

Figure 8: Operational Costs for all scenarios in Climate Zones 5, 6, and 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

The operational costs for the mixed-fuel gas home are less than the all-electric homes in Climate Zone 7 mainly because northern Michigan has especially high electricity costs compared to natural gas prices. However, Climate Zone 7 has a high number of residents on propane or electric resistance heating. Propane fuel is about two to three times more expensive than natural gas, making electric appliances an even more attractive option compared to combustion appliances.[61] Studies show that on average, propane customers would save $564/year in utility bills and electric resistance customers could save $748/year if instead they used a high-efficiency all-electric heat pumps.[62]

[61] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[62] https://map.rewiringamerica.org/states/michigan-mi

3. **Lifecycle Costs over 7 years:** The lifecycle costs include the home down payment (10% of the upfront costs) and the monthly operational costs. **The all-electric scenarios (2 and 3) have higher lifecycle costs than the current Michigan code in Climate Zone 7.** An all-electric 2021 IECC with insulation and air sealing amendments increases 7-year lifecycle costs by $7,300. The all-electric 2021 IECC increases lifecycle costs by $6,200 over 7 years.

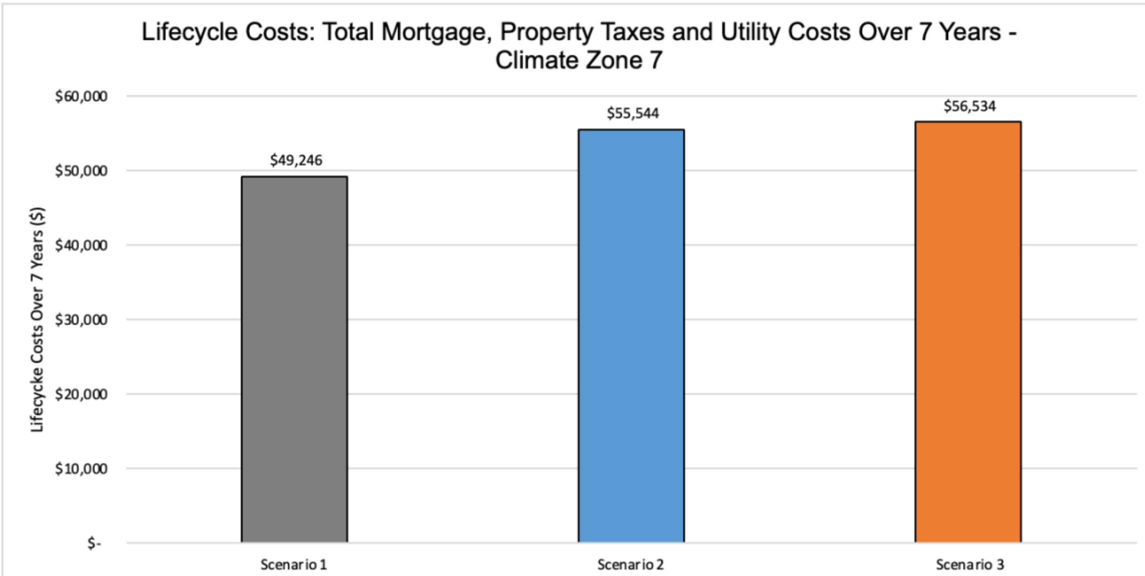

Figure 9: Lifecycle Costs for all scenarios in Climate Zone 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

Although the lifecycle costs are not competitive in Climate Zone 7, rising gas prices and declining electric appliance costs could make all-electric housing more cost-effective than mixed-fuel homes. **To ensure residents are prepared to transition to all-electric homes when affordable, Michigan should require Climate Zone 7 to build electric-ready homes.** Electric ready homes can still install gas appliances and leverage the currently lower gas utility costs, but the electric infrastructure will already be installed ensuring residents can have affordable retrofits to transition to all electric appliances when they are ready.

4. **Additional Benefits:** Although the all-electric scenarios in this analysis come at a premium compared to the mixed-fuel scenario in Climate Zone 7, there are many benefits to adopting all-electric that merit this investment. As laid out above, Climate Zone 7 can improve indoor air quality by eliminating gas appliances and adding mechanical ventilation. Climate Zone 7 can reduce moisture problems by increasing wall insulation and air sealing. Since Climate Zone 7 is considered a very cold climate, these amendments are most important to employ in this region. Finally, Climate Zone 7 will see greenhouse gas emission benefits as outlined above. This will help upper Michigan reduce its climate impacts and improve outdoor air quality.

To the Department of Licensing and Regulatory Affairs, Bureau of Construction Codes:
I'm writing to urge the incorporation of the 2021 IECC, **including the Zero Code Renewable Energy Appendi**x, into both the residential (part 10) and commercial (part 10a) sections of the Michigan Energy Code, now under revision. The Zero Code Appendix gives local jurisdictions the ability to require that new commercial, institutional and multi-family residential buildings procure enough renewable energy to achieve zero net carbon emissions, and incentivizes energy efficiency standards exceeding those of the 2021 code. This is a long overdue measure to begin to address the 39% of national greenhouse gas emissions accounted for by buildings.

Thank you for considering this comment.

Respectfully,
Ken Garber
[redacted]

Zach Waas Smith
Community Engagement Specialist
Office of Sustainability & Innovations
City of Ann Arbor
301 E Huron St., Ann Arbor, MI 48104
zwaassmith@a2gov.org

March 16, 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
LARA-BCC-Rules@michigan.gov

RE: 10a Michigan Energy Code (ORR# 2021-49 LR)

We are writing in support of including the IECC appendices, specifically Appendix CC, in the Michigan Commercial Building Code. Unlike the ASHRAE appendices, they are not specifically included in the current draft language.

The IECC 2021 Appendix CC (aka Zero Code) is a flexible framework that cities and states can use to help reach their building decarbonization goals. IECC 2021 Appendix CC combines energy efficiency and renewable energy to support the construction of code-compliant, zero carbon buildings that use clean energy. It applies to new commercial, industrial and mid- to high-rise residential buildings—the dominant building types being constructed in cities today.

A^2ZERO is Ann Arbor's plan for a just transition to carbon neutrality by 2030. Because two-thirds of Ann Arbor's greenhouse gas emissions come from buildings, Appendix CC will help Ann Arbor best serve its residents & businesses by creating a pathway toward safer, healthier, more comfortable, and more efficient buildings, all while preserving our state for future generations.

As a *voluntary* Appendix, it gives any Authorites Having Jurisdiction the option of adopting the appendix. It does not make the appendix mandatory across the State. This provides jurisdictions, including Ann Arbor, an important framework to reach their decarbonization goals if they choose to adopt the appendix.

In summary we support Appendix CC because it:

- Is voluntary for jurisdictions to adopt.
- Requires compliance with 2021 IECC, which represents about a 12% efficiency gain over the current MI code.
- Sets a minimum renewable energy requirement based on energy simulations or default values
- Provides an incentive for buildings to be designed & constructed to be more energy efficient than code requires, therefore protecting building owners from expensive retrofit costs.
- Encourages on-site renewable energy when feasible to build community resiliency.
- Supports off-site renewable energy procurement when necessary.
- 2021 IECC energy efficiency requirements cannot be traded with renewable energy.
- Establishes a consistent framework that local governments can modify for their specific needs and conditions, especially enabling them to meet their own climate goals.

Thank you for your time and consideration.

Sincerely,

Zach Waas Smith

20 N. Wacker Drive, Suite 1301
Chicago, Illinois 60606
312.587.8390 Main Line
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www.mwalliance.org

March 16, 2022

Keith Lambert
Bureau of Construction Codes
Department of Licensing and Regulatory Affairs
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

Re: MEEA's comments in support of the adoption of the 2021 International Energy Conservation Code for residential and commercial buildings

Dear Mr. Lambert and the Bureau of Construction Codes,

Thank you for the opportunity to provide comments on current update to the Michigan Energy Code. The Midwest Energy Efficiency Alliance (MEEA) is a member-based non-profit organization promoting energy efficiency to optimize energy generation, reduce consumption, create jobs and decrease carbon emissions in all Midwest communities. We have worked with previous Administrations on Michigan's building energy codes and are an active member of the Michigan Energy Codes Collaborative.

MEEA commends Bureau of Construction Codes (BCC) for recommending the adoption of the 2021 IECC without weakening amendments for residential construction, and with few weakening amendments for commercial construction. Updating the energy code is a great opportunity for the state to capitalize on the myriad benefits that stem from the adoption of a strong energy code. The adoption of the 2021 IECC without weakening amendments is cost-effective for Michigan[1] and provides users of the code with the flexibility to achieve compliance in a way that best suits their business while maintaining a beneficial baseline level of energy efficiency in all buildings. MEEA supports the adoption of the 2021 IECC without weakening amendments for residential and commercial buildings as the new statewide code for Michigan.

The 2021 IECC is cost effective for Michigan

The 2021 IECC sets a high but achievable standard for reducing energy waste while bringing the benefits of efficiency, resilience and comfort to building owners and occupants in Michigan. The efficiency provisions in the 2021 IECC will lower the energy consumption and demand of a building for its lifetime, which can be anywhere from 50-100+ years. This essential feature of a strong energy code will save residents money on their utility bills, reduce the impact buildings

[1] See: https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Michigan.pdf for the commercial cost effectiveness analysis and https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf for the residential cost effectiveness analysis conducted by DOE and PNNL

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have on the energy grid and lower GHG emissions. Updating to the 2021 IECC with no weakening amendments will also help ensure Michigan stays on track to meet the energy and climate goals established by the Whitmer administration. The most cost-effective time to install these energy-saving measures is during initial construction, so it is critical that these long-lasting waste reduction provisions remain in place in the energy code Michigan adopts.

Envelope improvements are essential for long-term comfort and resilience

The envelope improvements in the 2021 IECC will result in the construction of more comfortable and resilient buildings. A strong building envelope ensures that in times of extreme weather, buildings are able to better maintain comfortable temperatures. This is especially important during power outages or other natural disasters because it allows the building to maintain habitable temperatures for a longer period of time, providing a safe place for people to shelter in place during the first critical hours and days of a severe outage or natural disaster. Additionally, improvements in ceiling insulation and wall insulation in helps to ensure that homes are more comfortable and affordable to live in during both the summer cooling and winter heating season while also reducing the overall energy usage which keeps homeowner costs down making the home more affordable, especially when energy prices are higher.

The 2021 IECC allows compliance flexibility without sacrificing efficiency

The flexibility built into the 2021 IECC allows builders to choose a compliance path that fits their business model without compromising on efficiency. The performance and Energy Rating Index (ERI) pathways in the residential code allow builders to trade off efficiency in one place for improvements in another, providing flexibility for builders who prefer particular construction techniques. Rolling back any part of the code will put these pathways out of sync and misalign energy waste reduction savings across compliance pathways

Energy monitoring requirements in the commercial provisions of the 2021 IECC ensure buildings are performing as designed

The proposed provisions in the commercial energy code eliminate the energy monitoring requirements in the 2021 IECC. These are new provisions in the 2021 IECC and are essential to ensuring that the actual performance and energy use of the building is as designed. This is a simple way to confirm that presumed energy waste reduction is being achieved. This data will also be critical to understanding and identifying ways to make performance improvements and reduce energy use down the road – which is an essential step towards meeting established climate goals. As the saying goes, you can't manage what you don't measure.

The adoption of the 2021 IECC is a cost-effective way for Michigan to gradually increase the level of efficiency of residential and commercial buildings and remain a leader in the Midwest. We recommend the adoption of the 2021 IECC without weakening amendments as a way to reduce long-term energy use and costs for residents, create healthier and more comfortable indoor environments, and increase the resiliency of the building stock so new residential

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dwellings and commercial buildings last for the next 75-100 years. If you have any questions about this testimony, noted reports and references or general impact and analysis of building energy codes, please contact Nicole Westfall, Building Policy Manager for MEEA at nwestfall@mwalliance.org or 312-374-0918.

Sincerely,

Stacey Paradis
Executive Director

Submitted via Email: LARA-BCC-Rules@michigan.gov

March 14, 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division

American Chemistry Council Comments Supporting the Michigan Adoption of the 2021 International Energy Conservation Code for Residential and Commercial Buildings

The American Chemistry Council (ACC) thanks you for the opportunity to submit comments and recommend the adoption of the 2021 International Energy Conservation Code (IECC) with reference to ASHRAE 90.1-2019.

Chemistry is essential to the U.S. economy and plays a vital role in driving innovations that make our world safer, more sustainable, and more productive. Chemistry supports over 25% of the U.S. GDP and 9% of U.S. goods exports – a $486 billion enterprise. 529,000 skilled American jobs are provided by the business of chemistry. The U.S. is the 2nd largest global producer, providing 13% of the world's chemicals. Chemistry in Michigan pays $1.83 billion in wages and generates $138 million in state and local taxes.[1]

There are many reasons we support the Michigan adoption of these modern energy codes. Primarily, the energy savings that are realized by the people who live and own businesses in the state. The Department of Energy (DOE) determined the 2021 energy codes provide **cost-effective levels of energy efficiency** and performance for residential and commercial buildings in Michigan. Based on housing starts in Michigan the adoption of the 2021 Residential IECC would save $3,873,000 in the first year alone.[2] Likewise, based on new commercial construction numbers in Michigan the adoption of the 2021 IECC with reference to ASHRAE 90.1-2019 for commercial buildings would save $1,587,000 in the first year alone.[3]

This is especially important in order to address the **environmental justice issue of the affordable housing** needs of lower income households. According to the U.S. Energy Information Administration:

[1] See Michigan.pdf (americanchemistry.com)
[2] See Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan (energycodes.gov)
[3] See Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Michigan (energycodes.gov)

Across the United States, high utility bills are costing homeowners a significant portion of their monthly incomes. According to the most recent EIA Residential Energy Consumption Survey,[4] about one in five households reported reducing or forgoing basic necessities like food and medicine to pay an energy bill. Stronger energy codes and more widespread code compliance can help change the tide on this type of energy poverty. Improving compliance with residential energy codes opens up an array of economic and health benefits for homeowners, residents, local governments, and building officials, including:

- Reduced energy costs that yield monthly savings for owners and occupants, helping to boost the local economy and improving housing affordability by reducing utility costs.
- More comfortable and durable homes that better shield people from outdoor temperature extremes.
- Better protected occupant health from improved efficiency and indoor air quality.
- Greater market certainty for the building design and construction industry due to consistent implementation across jurisdictions.
- A level playing field for manufacturers, builders, and other building related industries.

Beyond the obvious energy savings benefits there are many other important reasons for Texas to update their building energy codes:

- **Job creation,** based on U.S. Census data on residential housing permits, it is estimated that over 80,000 residential one- and two-family homes have been permitted in Michigan since the last energy code update in late 2017.[5]
- **GHG emission reductions,** DOE estimates that the 30-year cumulative reduction of CO_2 emissions that Michigan would realize with the adoption of the 2021 residential provisions is equivalent to 11,460,000 metric tons.[6]
- **Resilience,** in a 2021 report the National Institute of Building Sciences found that adopting the latest building code requirements is affordable and saves $11 per $1 invested. Building codes have greatly improved society's disaster resilience, while adding only about 1% to construction costs relative to 1990 standards. The greatest benefits accrue to communities using the most recent code editions.[7]
- **Energy Security,** the International Energy Agency recognizes that energy efficiency can bolster regional or national energy security. By reducing overall energy demand, efficiency can reduce

[4] See Residential Energy Consumption Survey (RECS) - Energy Information Administration (eia.gov)
[5] See U.S. Census Bureau, Building Permits Survey, available at https://www.census.gov/construction/bps/
[6] See Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan (energycodes.gov)
[7] See Mitigation Saves: Mitigation Saves up to $13 per $1 Invested (nibs.org)

reliance on imports of oil, gas and coal. Energy efficiency can therefore play a crucial role in ensuring both long- and short-term energy security in a cost-effective manner.[8]

ACC is grateful for the opportunity to encourage and support the adoption of the 2021 International Energy Conservation Code (IECC) for all the great benefits these new codes would bring to the people in the State of Michigan.

Sincerely,

Amy Schmidt
American Chemistry Council
Director, Building and Construction

[8] See Energy security – Multiple Benefits of Energy Efficiency – Analysis - IEA

Electrification Coalition

1111 19th Street NW, Suite 406
Washington, DC, 20036

www.ElectrificationCoalition.org

March 16, 2022

Mr. Keith Lambert
Director, Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
611 W Ottawa St.
Lansing, MI 48933

Re: Michigan's 2021 Energy Conservation Code Adoption

Dear Director Lambert,

The Electrification Coalition (EC) is a national, nonpartisan, not-for-profit organization committed to promoting policies and actions that facilitate the deployment of electric vehicles (EVs) on a mass scale to combat the national security, economic, and public health impacts associated with our dependence on oil. We write in support of efforts to include EV-ready building code

Mass adoption of EVs is key to addressing the U.S.'s reliance on oil, which currently powers 91% of our nation's transportation system. **EV-Ready building codes will help accelerate the adoption and accessibility of EVs by enabling the future installation of EV charging stations in our homes and buildings.** EV-ready building codes will also keep retrofit construction costs down as EVs become mainstream. As a percentage of total new construction costs, EV-Ready costs are typically very low – an estimated 0.13% to 0.17% of the total project cost. EVSE installation at the time of new construction equates to a savings of approximately 80% when compared to a retrofit.

The EC is actively involved in Michigan's transition towards an electric transportation future. The Auto State is one of five states selected for the EC's EV Policy State Accelerator program to drive ambitious policy action across executive, legislative and regulatory venues at the state level to achieve widespread transportation electrification. In the past year, the EC has worked with a broad stakeholder group to identify and advance short-term policy opportunities to advance EV adoption. We hosted an EV Policy Bootcamp and developed an EV Policy Blueprint specific to Michigan, and have shared a number of policy tools and resources to assist state and local policymakers, including serving on the Electrification Working Group of the Governor's Council for Future Mobility and Electrification. The EC works with local governments in Michigan, through our Climate Mayors EV Purchasing Collaborative, to develop and implement innovative policies and strategies to increase EV sales and fleet procurement. EV-ready building codes are key to supporting those efforts.

In the interest of national and economic security, as well as the many other air quality and public health benefits of EVs, **we urge the Michigan Department of Licensing and Regulatory Affairs to move forward in the development of EV-ready building codes, including both commercial and residential codes, to address the needs of all property types including multi-family, single-family, and commercial buildings.**

Sincerely,

Ben Prochazka

Ben Prochazka
Executive Director
Electrification Coalition
[redacted]

Rule 1060 is not listed to be rescinded or amended.
As it currently reads, rule 1060 amends R101.1, R104.3 and R102.1.1.
R101.4.3 does not exist in the 2021 version of the IECC.
R102.1.1 does exist as titled “Above Code Programs” but it seems like the standards referenced when MI amended the 2009 code should be revised.

Rule 1060 should be amended strike the amendments to R102.1.1 and 104.3 or re-written

Rule 1066 is not listed to be rescinded or amended.
As it currently reads, rule 1066 amends R403.2.1, R403.2.2, R403.4, and R403.4.2
The sections as they appeared in the 2015 version have been completely re-written and the amendments of rule 1066 are no longer applicable to the sections R403.2.1, R403.2.2, R403.4, and R403.4.2 of the 2021 model code

Rule 1066 should be rescinded

Rule 1093 is not listed to be rescinded or amended.
As it currently reads, rule 1093 amends C107.1
This section as it appeared in the 2015 version has been re-number and the amendments of rule 1093 are no longer applicable to section C107.1 in the 2021 model code

Rule 1093 should be rescinded

Rule 1092 is not listed to be rescinded or amended
As it currently reads rule 1092 amends C102.1.1 and C103.1
C102.1.1 does exist as titled “Above Code Programs” but the MI amendment references outdated standards and “mandatory” requirements of chapter 4. The words “mandatory” and “prescriptive” within the chapter 4 requirements have been removed from the 2021 model code

Rule 1092 should be amended to strike the amendments to C102.1.1 or re-written

Rule 1071 is not listed to be rescinded or amended.
As it is currently written rule 1071 amends table R405.5.2(1).
This table as it appeared in the 2015 version is no longer applicable to the 2021 code due to significant changes.

Rule 1071 should be rescinded

Rule 1060e is listed to be rescinded
As it was written, rule 1060e focused the scope of the MI energy code to the boundaries of Michigan. the changes to section R301.1 Table R301.1 and Figure R301.1 should remain. Table R301.3 should remain as found in the 2021 model code

Rule 1060e should be re-written as follows:
Rule 1060e. Section **R**301.1**,** ~~and~~ Table~~s~~ **R**301.1 ~~and 301.3(2) of the code are amended~~ and Figure **R**301.1~~a is added to the code~~ **are amended** to read as follows: **R**301.1 General. Climate zones from figure~~s~~ **R**301.1, ~~301.1a~~ or table **R**301.1 shall be used in determining the applicable requirements of this code.(the referenced table and figure shown to be struck should remain)

Rule 1096 is listed to be rescinded
As it was written, rule 1096 focused the scope of the MI energy code to the boundaries of Michigan. the changes to section C301.1 Table C301.1 and Figure C301.1 should remain. Table C301.3 should remain as found in the 2021 model code

Rule 1096 should be re-written as follows:
Rule 1096. Section C301.1**,** ~~and~~ Table~~s~~ C301.1 ~~and C301.3(2) of the code are amended~~ and Figure C301.1~~a is added to the code~~ **are amended** to read as follows: C301.1 General. Climate zones from figure~~s~~ C301.1, ~~301.1a~~ or table C301.1 shall be used in determining the applicable requirements of this code.(the referenced table and figure shown to be struck should remain)

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
Phone (517) 241-9303
Fax (517) 241-0130
Email: johnsona39@michigan.gov

ACTION:

DATE: 03/16/2022

NAME: fMichigan Air Conditioning Contractors Assoc.

REPRESENTING: Itself

ADDRESS: 602 W. Ionia

CITY: Lansing

STATE: MI

ZIP: 48933

PHONE: (517) 763-7892

FAX:

EMAIL: mjdsmith@miacca.org

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.7 Building Cavities.

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**Bold & underline proposed added text**

Building framing cavities not located within the conditioned space shall not be used as ducts or plenums.

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.7 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Prohibiting building cavities from being used as return air ducts within the conditioned space in accordance with Section M1601.1.1 of the Michigan Residential Code will add at least $150 per return air register. So in a typical 3 bedroom home with 4-5 return air registers the added cost will be at least $600-$750 more and save zero energy. The BCC published document titled "2015 Michigan Residential Code Errors and Conflicts" has determined such a prohibition is not cost effective.

☐ **Back Up/Graphic Material Included**

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
Phone (517) 241-9303
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ACTION:

DATE: 03/16/2022

NAME: fMichigan Air Conditioning Contractors Assoc.

REPRESENTING: Itself

ADDRESS: 602 W. Ionia

CITY: Lansing

STATE: MI

ZIP: 48933

PHONE: (517) 763-7892

FAX:

EMAIL: mjdsmith@miacca.org

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.4 - "new exemption"

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**Bold & underline proposed added text**

sheet titled: R403.3.4 - "new exemption"

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.4 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Requiring ducts to be sealed when the ducts are located entirely within the condition space it is serving, is not "cost effective" . This "cost effective" rationale was and is being used by the BCC in its published "2015 Michigan Residential Code Errors and Conflicts" document, under Duct Construction. Additionally attached is a supporting analysis by a mechanical engineer who is also a RESNET HERS Rater and LEED AP.

☐ **Back Up/Graphic Material Included**

BCC-3016 (05/19)

R403.3.4 - "new exemption"

PROPOSED LANGUAGE: Show proposed text in accordance with the following format:
Strikeout/**Bold & underline proposed added text**

R403.3.4 Sealing. Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with either the *International Mechanical Code* or *International Residential Code*, as applicable.

<u>Exceptions:</u>
<u>For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), sealing shall not be required where the ducts are located entirely within the condition space it is serving.</u>

2015 Michigan Residential Code Errors and Conflicts

The following are errors and conflicts that have been identified at this point. The Bureau of Construction Codes has reviewed these issues. The Director of Department of Licensing and Regulatory Affairs has delegated the authority to make, and has approved, the following interpretations which are advisory.

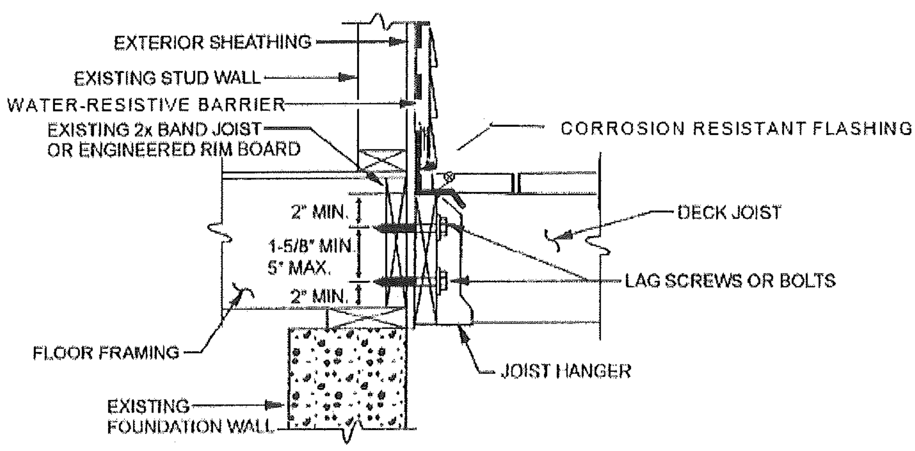
Stair Geometry

In the Michigan Residential Code Section R311.7.4.1 Riser height and Section R311.7.4.2 Tread depth are the correct requirements for stair geometry and they are the promulgated state rules consistent with MCL 125.1513d. These provisions shall replace the provisions in Sections R311.7.5.1 and R311.7.5.2 respectively; however the exceptions in R311.7.5.1 are still valid.

Vapor Retarders

There are 2 sections on vapor retarders in the 2015 Michigan Residential Code, R601.3 and R702.7. It has been determined by the department that section R601.3 is the section that is to be enforced by all enforcing agencies.

Figure R507.2.1(2) was obviously corrupted during the publication of the rules and was not noticed until it was published by the International Code Council. The figure that must be used by all enforcing agencies is now provided.



For SI: 1 inch = 25.4 mm.

FIGURE R507.2.1(2)
PLACEMENT OF LAG SCREWS AND BOLTS IN BAND JOISTS

Carbon Monoxide Detector Location

MRC section R315 does not provide the location of the carbon monoxide detectors. The location of these devices is found in the 1972 PA 230 section 4f, MCL 125.1504f: "A carbon monoxide device shall be located in the vicinity of the bedrooms, which may include 1 device capable of detecting carbon monoxide near all adjacent bedrooms; in areas within the dwelling adjacent to an attached garage; and in areas adjacent to any fuel-burning appliances." They are to be installed in accordance with manufacturer's recommendations and should not be placed within fifteen feet of fuel-burning heating or cooking appliances such as gas stoves, furnaces or fireplaces or in or near very humid areas such as bathrooms.

Duct Construction

The Michigan Residential Code (MRC) Sections N1103.2.3 and M1601.1.1 conflict regarding the use of building framing cavities for plenums. To resolve the conflict we look at the definition of "cost effective" in MCL 125.1502a(p), and MCL 125.1504(3)(f) and (g).

MCL 125.1504a(p) states:
(p) "*Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:*

(i) Considers the perspective of a typical first-time home buyer.

(ii) Considers benefits and costs over a 7-year time period.

(iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.

(iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features."

MCL 125.1504(3)(f) and (g) state:
"*(3) The code shall be designed to effectuate the general purposes of this act and the following objectives and standards:*
(f) To provide standards and requirements for cost-effective energy efficiency that will be effective April 1, 1997.
(g) Upon periodic review, to continue to seek ever-improving, cost-effective energy efficiencies."

The conflict is resolved in favor of M1601.1.1 as MRC Section M1601 is the definitive section on duct construction. This decision is based on MRC Section R102.1 (Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.) and that Section N1103.2.3 has not been shown to meet the definition of cost effective.

Combustible Insulation

Section R302.13 is the language that is promulgated by the department and is the language that must be used. Section R302.14 shall treated as if it was deleted which was the intent.

Roof Loading Data Sheet

Figure 802.10.1 under Exposure Factor C the designation should be B C and D to be consistent with the ASCE 7-10 standard. The text for the exposures is correct but when A was deleted to be consistent with standard an auto correct function relabeled the remaining exposures A, B and C. This was not caught before publication. If the text is used for providing the requested information and A, B and C designation replaced with B. C and D respectively the information will be correct.

Mechanical Resolution

September 7, 2018

Allendale Heating Company, Inc.
11672 60th Avenue – P.O. Box 296
Allendale, Michigan 49401

RE: Duct Sealing

To whom it may concern,

Mr. Irvin Polk issued a 2015 Michigan Residential Code Errors and Conflicts letter to clarify code issues in the 2015 code. In this letter, it addresses the conflict in the code between N1103.2.3 and M1601.1.1 regarding the use of building framing cavities for plenums. Mr. Polk utilized and applied the definition of "cost effective" in MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) to conclude that using building framing cavities for plenums was indeed allowed based on 2015 Michigan Residential Code R102.1. In reviewing and researching this letter, Mr. Polk and I draw the same conclusion in regards to plenums and "cost effective."

Using this same logic, duct sealing ductwork located in a conditioned space would also not meet the definition of "cost effective" under MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) for the very same reasons that the 2015 Michigan Residential Code Error and Conflict determined using building framing cavities for plenums does not meet the definition of "cost effective". Both of these topics are essentially used in the same conversation when discussing building energy efficiency of the HVAC duct system and its' impact on building performance.

Building energy efficiency losses occur when conditioned air is transferred to the environment outside of the building thermal envelope. This occurs via conduction, convection, and radiation through the building structure materials and assemblies. The ways to reduce these losses are by using higher R value building materials, better building fenestration, and decreasing the amount of uncontrolled air leakage into (infiltration) or out of (exfiltration) a building through cracks and seams.

When ductwork is located in a conditioned space, any duct leakage from the unsealed ductwork enters an already conditioned space within the building thermal envelope. Therefore, no energy loss occurs directly related to the sealed and/or unsealed ductwork from a conditioned space to an unconditioned space. Any energy loss would occur from the uncontrolled air leakage through the building envelope and not by an unsealed duct in a conditioned space. There are discussions about how an unsealed duct in a floor/ceiling assembly will positively pressurize the cavity and leak through the exterior cracks. But whether the air pressurizes the cavity or a bedroom (register location), the positive air will find its' way to the crack. Therefore, the real solution to saving energy costs is to seal the crack not necessarily sealing the duct.

1321 17 Mile Road • Cedar Springs, MI 49319 • Phone 616.439.3311 • Fax 616.439.3315

Sealing ductwork in an **<u>Un</u>**conditioned space is essential as any duct leakage is lost directly outside the thermal envelope. This is the very reason why code requires duct pressurization testing for ductwork located outside the building thermal envelope (unconditioned space) but does not require the duct pressurization testing for ductwork located inside (conditioned space) the thermal envelope. Blower door testing of the building thermal envelope is required by code no matter where the ductwork is located. This further implies that the code is more concerned with building infiltration, in regards to building efficiency, than to ductwork losses to a conditioned space.

Sealing ductwork in a conditioned space provides better comfort for the homeowner, not energy efficiency nor economic benefits. Duct sealing for comfort helps assure that the necessary airflow is provided to a specific space inside the building thermal envelope. However, when discussing building energy efficiency and economic benefits, a homeowner is better to spend money on reducing building leaks, better insulation, better windows, better doors, as these are the areas where building energy efficiency is lost at the building envelope. Not duct sealing ductwork in a conditioned space.

As stated in the beginning, duct sealing ductwork located in a conditioned space does not meet the definition of "cost effective" under MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) for the very same reasons that the 2015 Michigan Residential Code Error and Conflict determined using building framing cavities for plenums does not meet the definition of "cost effective".

Please feel free to call with any questions that you may have.

Respectfully,

Mechanical Resolution

Aaron J. Sedine, P.E.
Mechanical Engineer
Resnet Hers Rater
Leed AP

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
Phone (517) 241-9303
Fax (517) 241-0130
Email: johnsona39@michigan.gov

ACTION:

DATE: 03/16/2022

NAME: fMichigan Air Conditioning Contractors Assoc.

REPRESENTING: Itself

ADDRESS: 602 W. Ionia

CITY: Lansing

STATE: MI

ZIP: 48933

PHONE: (517) 763-7892

FAX:

EMAIL: mjdsmith@miacca.org

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.5 Duct testing - Exception (new)

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**Bold & underline proposed added text**

1. A duct air-leakage test shall not be required for ducts serving ventilation systems that are not integrated with ducts serving heating or cooling systems.
2. A duct air-leakage test shall not be required for ducts located in the conditioned space.

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.5 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Ducts located in the conditioned space and leak air in to the same conditioned space does not contribute to the overall buildings increased energy use. Therefore to require a $300-$500 air duct leakage test is not cost effective as it will save zero energy.

☐ **Back Up/Graphic Material Included**

BCC-3016 (05/19)

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909
LARA-BCC-Rules @michigan.gov
(517) 482-5519

Dear Director Hawks, Deputy Director Pendleton, and Director Lambert,

Thank you for the opportunity to comment regarding the proposed rule sets (2021 – 48 LR & 2021 – 49 LR) to amend the Michigan Energy Code. Michigan Energy Innovation Business Council (Michigan EIBC) is a business trade association representing over 140 companies across a full range of advanced energy industries, including energy efficiency, electric vehicles (EVs), renewables, demand response technologies, energy storage, and others. Michigan EIBC's mission is to grow Michigan's advanced energy economy by fostering opportunities for innovation and business growth for the advanced energy industry in the state.

Overall Comments

Updating our building codes is one of the greatest tools the State of Michigan holds to make necessary advancements in energy efficiency, advanced mobility, and building electrification. The proposed drafts from the Michigan Department of Licensing and Regulatory Affairs (LARA)'s Bureau of Construction Codes (BCC) on Michigan's residential and commercial energy codes will make necessary improvements in energy efficiency in buildings and homes across the state. The 2021 residential edition of the International Energy Conservation Code (IECC) represents approximately a 12% improvement in efficiency through more efficient thermal envelopes, improved mechanical system efficiency, improved lighting, and other cost-effective improvements compared to the 2015 model code, which is similar to Michigan's current code. Implementing the residential IECC will save Michigan residents money on their energy bills, continue to support the growing industry in energy efficiency, and advance the work in futureproofing Michigan's building stock.

Michigan EIBC strongly urges LARA to push further to ensure Michigan continues this track. Specifically, Michigan EIBC recommends including amendments to require EV charging readiness in both the residential and commercial codes. Additionally, in the residential code, the state should adopt requirements for smart thermostats and electric-readiness provisions. And in the commercial code, we strongly urge LARA to add the energy monitoring requirements from the 2021 IECC back into the Michigan code, as well as to consider nominal renewable requirements and storage readiness. These additions will ensure Michigan residents can save money on their electric bills with improved efficiency and demand response, can charge their cars, and are able to make other more cost-effective home and building improvements in the future.

EV Readiness: Residential and Commercial Codes

Michigan EIBC strongly urges the BCC to include language requiring that all new homes are EV ready and commercial buildings/multi-family housing with parking include EV ready spaces. Both of these recommendations were included in the draft of the MI Healthy Climate Plan and the Michigan Council on Future Mobility & Electrification's 2021 Report.[1, 2] Additionally, cities in Michigan are already moving in this direction: Ann Arbor adopted an EV charging and readiness ordinance for new developments last year, and Lansing is currently considering a similar ordinance.[3, 4] These additions will not only support Michigan's advanced mobility future and economy, but also, they will save residential customers and commercial building owners money and they will help to protect public health.

Due to improved technology and increased consumer demand, the transition to EVs is well underway, and Michigan's future buildings should be ready for this shift.

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[1] Michigan Department of Environment, Great Lakes, and Energy. "Draft MI Healthy Climate Plan." January 14, 2022. Available at https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.

[2] Michigan Department of Labor and Economic Opportunity. "Council on Future Mobility and Electrification 2021 Report." Available at https://www.michigan.gov/documents/leo/CFME_Report_2021_738091_7.pdf.

[3] Stanton, Ryan. MLive. "Ann Arbor council Oks ordinance requiring EV parking for new developments." January 19, 2021. Available at https://www.mlive.com/news/ann-arbor/2021/01/ann-arbor-council-oks-ordinance-requiring-ev-parking-for-new-developments.html#:~:text=For%20multi%2Dfamily%20housing%20developments,and%2065%25%20EV%2Dcapable.

[4] Wiewgorra, Luisa. Fox 47 News. "Lansing could adopt requirements for EV charging stations." Available at https://www.fox47news.com/neighborhoods/downtown-old-town-reo-town/lansing-could-adopt-requirement-for-ev-charging-stations

Auto manufacturers are embracing the transition to EVs. For example, both General Motors and Ford made announcements in the past year regarding their plans to switch their manufacturing to EVs.[5, 6] Across the U.S., EV sales increased by 80 percent from 2017 to 2018, and the number of EVs on U.S. roads is projected to grow from 1 million vehicles at the end of 2018 to 18.7 million by 2030. To charge these new EVs, the U.S. will need 9.6 million charge ports -- a substantial portion of which will be installed where they are most useful for consumers: at homes and businesses.

Unfortunately, it can be costly and challenging to install charging stations at existing residential and commercial structures due to the potential need for extensive electrical upgrades. This often requires the installation of conduit through existing concrete or drywall to connect the electric vehicle supply equipment (EVSE) to electrical service. According to research from the New Buildings Institute, making homes EV ready at the time of construction can save customers $1,000 to $2,500 in retrofit costs, if they choose to install a charger at a later time. For commercial buildings and multi-family residences, EV ready construction can save about $7,000 to $8,000 in retrofit costs according to a study conducted by the California Air Resources Board.[7] Therefore, it is more cost-effective to ensure a new home or commercial building is EV ready when it is being built or undergoing major renovations than to conduct these extensive electrical upgrades when a charger is later installed.

More accessible EV charging infrastructure is also necessary to reduce carbon emissions and local air pollution. In 2018, the transportation sector was the second largest source of Michigan's greenhouse gas emissions, representing 28 percent of total emissions.[8] In order to meet Governor Whitmer's goal under Executive Directive 2020-10 of 100 percent carbon neutrality in Michigan by 2050, policies must be put in place to reduce transportation sector greenhouse gas emissions and

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[5] Eisenstein, Paul A. "GM to go all-electric by 2035, phase out gas and diesel engines." Available at https://www.nbcnews.com/business/autos/gm-go-all-electric-2035-phase-out-gas-diesel-engines-n1256055.

[6] Wayland, Michael. "Ford ups EV investments, targets 40% electric car sales by 2030 under latest turnaround plan." Available at https://www.cnbc.com/2021/05/26/ford-ups-ev-investments-targets-40percent-electric-car-sales-by-2030-under-latest-turnaround-plan.html#:~:text=Ford%20Motor%20said%20Wednesday%20it,than%20%2430%20billion%20through%.

[7] California Air Resources Board. "EV Charging Infrastructure: Nonresidential Building Standards." November 15, 2019. Available at ww2.arb.ca.gov/sites/default/files/2020-08/CARB_Technical_Analysis_EV_Charging_Nonresidential_CALGreen_2019_2020_Intervening_Code.pdf.

[8] Michigan Department of Environment, Great Lakes, and Energy. "Draft MI Healthy Climate Plan." January 14, 2022. Available at https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.

to support the transition from gas-powered vehicles to EVs in the state. Additionally, according to the Health Effects Institute, "air pollution is one of the top-ranking factors for death and disability, with vehicle emissions [being] the main contributor to outdoor air pollution."[9] To both improve air quality and reduce emissions, it is necessary that Michigan prepares its future homes and businesses with the infrastructure needed to switch to EVs.

Michigan EIBC recommends the following EV readiness language be added to the residential code, including new definitions, and new Section R404.5 and revisions to Table R405.2 and Table R406.2:

Add new definitions as follows:

> **ELECTRIC VEHICLE (EV).** An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current. Plug-in hybrid electric vehicles are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats and the like, are not considered electric vehicles.
>
> **ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE).** The conductors, including the ungrounded, grounded, and equipment grounding conductors and the *electric vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *electric vehicle*.
>
> **LEVEL 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT (Level 2 EVSE).** *Electric Vehicle Supply Equipment* capable of providing AC Level 2 EV charging.
>
> **EV READY SPACE.** A designated *parking space* that is provided with an electrical circuit capable of supporting an installed *Level 2 EVSE* in close proximity to the proposed location of the EV parking space.

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[9] GreenBiz. "Electric bus fleets are the latest tool for improving air quality." Available at https://www.greenbiz.com/article/electric-bus-fleets-are-latest-tool-improving-air-quality.

Add new section as follows:

R404.5 Electric vehicle charging infrastructure. Electric infrastructure for the current and future charging of *electric vehicles* shall be installed in accordance with this section*. EV ready spaces* are permitted to be counted toward meeting minimum parking requirements.

R404.5.1 One- and two- family dwellings and townhouses. One- and two-family dwellings and townhouses with a dedicated attached or detached garage or on-site parking spaces and new detached garages shall be provided with one *EV ready space* per *dwelling unit.* The branch circuit shall meet the following requirements:

1. A 208/240-volt circuit installations, including panel capacity, raceway wiring, receptacle, and circuit overprotection devices that are able to provide Level 2 charging
2. Terminates at a junction box or receptacle located within 3 feet (914 mm) of the parking space, and
3. The electrical panel directory shall designate the branch circuit as “For electric vehicle charging” and the junction box or receptacle shall be labelled “For electric vehicle charging”.

R404.5.2 Group R occupancies. Parking facilities serving Group R-2, R-3 and R-4 occupancies shall comply with Section C405.15.

Revise table as follows:

TABLE R405.2
REQUIREMENTS FOR TOTAL BUILDING PERFORMANCE

SECTION [a]	TITLE
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
R404.5	Electric vehicle charging infrastructure

Revise table as follows:

TABLE R406.2
REQUIREMENTS FOR ENERGY RATING INDEX

SECTION [a]	TITLE
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
<u>R404.5</u>	<u>Electric vehicle charging infrastructure</u>
R406.3	Building thermal envelope

Michigan EIBC recommends the following EV readiness language be added to the commercial code, including new definitions, revisions to C401.2.2 and and Table C405. 12.2, and new section C405.14:

Add new definitions as follows:

<u>**AUTOMATIC LOAD MANAGEMENT SYSTEMS (ALMS).** A control system that allows multiple connected *EVSE* to share a circuit or panel and automatically reduce power at each charger, reducing the total connected electrical capacity of all *EVSE*.</u>

<u>**ELECTRIC VEHICLE (EV).** An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current. Plug-in hybrid electric vehicles are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats and the like, are not considered electric vehicles.</u>

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors and the *electric vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *electric vehicle*.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) SPACE. A parking space that is provided with a dedicated *EVSE*.

EV CAPABLE SPACE. A parking space that is provided with some of the infrastructure necessary for the future installation of an *EVSE* – such as conduit, raceways, electrical capacity, or signage – or reserved physical space for such infrastructure.

EV READY SPACE. A parking space that is provided with an electrical circuit capable of supporting an installed *EVSE*.

Revise text as follows:

C401.2.2 ASHRAE 90.1
Commercial buildings shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1 and Section C405.14.

Revise table as follows:

TABLE
C405.12.2 ENERGY USE CATEGORIES

LOAD CATEGORY	DESCRIPTION OF ENERGY CUSE
Total HVAC system	Heating, cooling and ventilation, including but not limited to fans, pumps, boilers, chillers, and water heating. Energy used by 120-volt equipment, or by 208/120-volt equipment that is located in a building where the main service is 480/277-volt power, is permitted to be

	excluded from total HVAC system energy use.
Interior lighting	Lighting systems located within the building.
Exterior lighting	Lighting systems located on the building site but not within the building.
Plug loads	Devices, appliances and equipment connected to convenience receptacle outlets.
Process load	Any single load that is not included in HVAC, lighting or plug load category and that exceeds 5 percent of the peak connected load of the whole building, including but not limited to data centers, manufacturing equipment, and commercial kitchens.
Electric vehicle charging	*Electric vehicle* charging loads.
Building operations and other miscellaneous	The remaining loads not included in this table, including but not limited to vertical transportation systems, automatic doors, motorized shading systems, ornamental fountains, ornamental fireplaces, swimming pools, in-ground spas and snow-melt systems.

Add new sections as follows:

C405.14 Electric vehicle charging infrastructure. Parking facilities shall be provided with electric vehicle charging infrastructure in accordance with this section and Table C405.14 based on the total number of parking spaces and rounded up to the nearest whole number*. EVSE, EV ready spaces* and *EV capable spaces* may be counted toward meeting minimum parking requirements*. EVSE spaces* may be used to meet requirements for *EV ready spaces* and *EV capable spaces. EV ready spaces* may be used to meet requirements for *EV capable spaces.* An *ALMS* may be used to reduce the total electrical capacity required by *EVSE spaces* provided that all *EVSE spaces* are capable of simultaneously charging at a minimum rate of 1.4 kW. Where more than one parking facility is provided on a building site, the number of parking spaces required shall be calculated separately for each parking facility.

Exception: In parking garages, the conduit required for *EV capable spaces* may be omitted provided the parking garage electrical service has no less than 1.8 kVA of additional reserved capacity per *EV capable space.*

TABLE C405.14
ELECTRIC VEHICLE CHARGING INFRASTRUCTURE REQUIREMENTS

OCCUPANCY	*EVSE SPACES*	*EV READY SPACES*	*EV CAPABLE SPACES*
Group B Occupancies	15%	NA	40%
Group M Occupancies	25%	NA	40%
R-2 Occupancy	NA	100%[a]	NA
All other Occupancies	10%	NA	40%

a. Or one *EV ready space* per *dwelling unit.*

C405.14.1 EV Capable Spaces. *EV Capable Spaces* shall be provided with electrical infrastructure that meets the following requirements:

1. Conduit that is continuous between a junction box or outlet located within 3 feet (914 mm) of the parking space and an electrical panel serving the area of the parking space
2. The electrical panel to which the conduit connects shall have sufficient dedicated physical space for a dual-pole, 40-amp breaker

3. The conduit shall be sized and rated to accommodate a 40-amp, 208/240-volt branch circuit and have a minimum nominal trade size of 1 inch
4. The electrical junction box and the electrical panel directory entry for the dedicated space in the electrical panel shall have labels stating "For future *electric vehicle* charging"

C405.14.2 EV Ready Spaces. The branch circuit serving *EV Ready Spaces* shall meet the following requirements:

1. Wiring capable of supporting a 40-amp, 208/240-volt circuit,
2. Terminates at an outlet or junction box located within 3 feet (914 mm) of the parking space,
3. A minimum capacity of 1.8 kVA.
4. The electrical panel directory shall designate the branch circuit as "For electric vehicle charging" and the junction box or receptacle shall be labelled "For electric vehicle charging,"

C405.14.2 EVSE Spaces. The *EVSE* serving *EVSE spaces* shall be capable of supplying not less than 6.2 kW to an electric vehicle and shall be located within 3 feet (914 mm) of the parking space.

Building Electrification and Demand Response: Residential Code
Michigan EIBC encourages LARA to include readiness provisions for building electrification and important building-grid integration technologies, including smart thermostats, into the residential code to further save Michigan residents money, achieve Michigan's carbon reduction goals, and reduce indoor air pollution. According to the draft MI Healthy Climate Plan, "the electrification of Michigan homes and businesses is a promising tool for reducing carbon emissions," and building electrification "has the potential to save residents real money on their utility bills."[10] An analysis from Rocky Mountain Institute found that all-electric new construction is more economical to build than homes with gas appliances, with lower upfront costs on devices, installation, and gas interconnection.[11] The study

[10] Michigan Department of Environment, Great Lakes, and Energy. "Draft MI Healthy Climate Plan." January 14, 2022. Available at https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.
[11] McKenna, Shah, & Louis-Prescott. RMI. "All-Electric New Homes: A Win for the Climate and the Economy." October 15, 2020. Available at https://rmi.org/all-electric-new-homes-a-win-for-the-climate-and-the-economy/.

also found that all-electric homes resulted in far fewer carbon emissions than mixed-fuel homes overall, which is important for reaching the administration's goal of 2050 carbon neutrality. Additionally, gas appliances are a primary source of pollution inside homes and switching to electric appliances and heating can reduce respiratory symptoms.[12]

Smart thermostats are another tool that is relatively inexpensive and a proven technology for reducing emissions while further ensuring the efficient operation of a building. As Michigan continues to move its sources of energy toward renewables, buildings must be prepared to aid in this transition by not just reducing baseline energy use but reducing energy use at key times during the day to match grid needs, which will also help reduce utility costs for Michigan residents. In particular, the draft MI Healthy Climate Plan recommends the state adopt a renewable portfolio standard of 50% by 2030, with a plan to end its use of coal-fired power by 2035. It is critical that new buildings be ready to support this increase in intermittent resources by using demand response and smart thermostats to effectively manage load. Smart thermostats also can save customers money on their utility bills, with potential savings of approximately $140 – $200 per year, possibly in addition to monetary utility incentives paid to the customer.[13]

Michigan EIBC recommends the following electric readiness language be added to the residential code, including new definitions, revisions to R401.2.5, R401.3, R402.1, R405, R406, and new section R404.6:

Add new text as follows:

> **R103.2.4 Electrification system.** The construction documents shall provide details for additional electric infrastructure, including branch circuits, conduit, or pre-wiring, and panel capacity in compliance with the provisions of this code.

Add new text as follows:

> **R105.2.5 Electrical rough-in inspection.** Inspections at electrical rough-in shall verify compliance as required by the code and the approved plans and

[12] Asthma Initiative of Michigan. "Indoor Aire Quality." Available at https://getasthmahelp.org/indoor-air-quality.aspx

[13] Smart Energy Consumer Collaborative. "Is a smart thermostat a worthwhile investment for your home?" Available at https://www.whatissmartenergy.org/featured-article/is-a-smart-thermostat-a-worthwhile-investment-for-your-home.

specifications as to the locations, distribution, and capacity of the electrical system.

Revise numbering as follows:

~~R105.2.5~~ R105.2.6 Final inspection.

Add new definitions as follows:

ALL-ELECTRIC BUILDING. A *building* that contains no *combustion equipment*, or plumbing for *combustion equipment,* installed within the *building*, or *building site.*

APPLIANCE. A device or apparatus that is manufactured and designed to utilize energy and for which this code provides specific requirements.

COMBUSTION EQUIPMENT. Any *equipment* or *appliance* used for space heating, *service water heating*, cooking, clothes drying, or lighting that uses *fuel gas* or *fuel oil*.

EQUIPMENT. Piping, ducts, vents, control devices and other components of systems other than appliances that are permanently installed and integrated to provide control of environmental conditions for buildings. This definition shall also include other systems specifically regulated in this code.

FUEL GAS. A natural gas, manufactured gas, liquified petroleum gas or a mixture of these.

FUEL OIL. Kerosene or any hydrocarbon oil having a flash point not less than 100°F (38°C).

MIXED-FUEL BUILDING. A *building* that contains *combustion equipment* or includes piping for *combustion equipment*.

Revise text as follows:

R401.2.5 Additional energy efficiency. This section establishes additional requirements applicable to all compliance approaches to achieve additional energy efficiency.

1. For *all-electric buildings* complying with Section R401.2.1, one of the additional efficiency package options shall be installed according to Section R408.2.

2. For mixed-fuel buildings complying with Section R401.2.1, the building shall be required to install either R408.2.1 or R408.2.5 of the additional efficiency package options, and any two of R408.2.2, R408.2.3, or R408.2.4 of the additional efficiency package options.

~~2~~3. For buildings complying with Section R401.2.2, the building shall meet one of the following:

~~2~~3.1. *All-electric buildings* shall have ~~O~~one of the additional efficiency package options in Section R408.2 ~~shall~~ ~~be~~ installed without including such measures in the proposed design under Section R405; or

~~2~~3.2. The proposed design of the *all-electric building* ~~building~~ under Section R405.3 shall have an annual energy cost that is less than or equal to the 95 percent of the annual energy cost of the standard reference design~~.~~; or

3.3 Mixed-fuel buildings shall have either R408.2.1 or R408.2.5 of the additional efficiency package options, and any two of R408.2.2, R408.2.3, or R408.2.4 of the additional efficiency package options installed without including such measures in the proposed design under Section R405; or

3.4 The proposed design of the mixed-fuel building under Section R405.3 shall have an annual energy cost that is less than or equal to 85 percent of the annual energy cost of the standard reference design.

~~3~~4. For buildings complying with the Energy Rating Index alternative Section R401.2.3, the Energy Rating Index value shall be at least 5 percent less than the Energy Rating Index target specified in Table R406.5.

The options selected for compliance shall be identified in the certificate required by Section R401.3.

Revise text as follows:

R401.3 Certificate. A permanent certificate shall be completed by the builder or other approved party and posted on a wall in the space where the furnace is located, a utility room or an approved location inside the building. Where located on an electrical panel, the certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label or other required labels. The certification shall indicate the following:

4. The types, sizes, fuel sources, and efficiencies of heating, cooling and service water heating equipment. Where a gas-fired unvented room heater, electric furnace or baseboard electric heater is installed in the residence, the certificate shall indicate “gas-fired unvented room heater,” “electric furnace” or “baseboard electric heater,” as appropriate. An efficiency shall not be indicated for gas-fired unvented room heaters, electric furnaces and electric baseboard heaters.

8. The fuel sources for cooking and clothes drying equipment.

9. Where combustion equipment is installed, the certificate shall indicate information on the installation of additional electric infrastructure including which *equipment* and/or *appliances* include additional electric infrastructure, capacity reserved on the electrical service panel for replacement of each piece of combustion *equipment* and/or *appliance*

R402.1 General. The building thermal envelope shall comply with the requirements of Sections R402.1.1 through R402.1.5.

Exceptions:

1. The following low-energy buildings, or portions thereof, separated from the remainder of the building by *building thermal envelope assemblies* complying with this section shall be exempt from the building thermal envelope provisions of Section R402.
    1. Those containing no *combustion equipment* with a peak design rate of energy usage less than 3.4 Btu/h·ft2 (10.7 W/m2) or 1.0 watt/ft2 of floor area for space conditioning purposes.
    2. Those containing no *combustion equipment* that do not contain *conditioned space*.

Add new text as follows:

R404.6 Additional electric infrastructure. *Combustion equipment* shall be installed in accordance with this section.

R404.6.1 Equipment serving multiple units. *Combustion equipment* that serves multiple *dwelling units* shall comply with Section C405.16.

R404.6.2 Combustion water heating. Water heaters shall be installed in accordance with the following:

1. A dedicated 240-volt branch circuit with a minimum capacity of 30 amps shall terminate within 3 feet (914 mm) from the water heater and be accessible to the water heater with no obstructions. Both ends of the branch circuit shall be labeled with the words "For Future Heat Pump Water Heater" and be electrically isolated.
2. A condensate drain that is no more than 2 inches (51 mm) higher than the base of the installed water heater and allows natural draining without pump assistance shall be installed within 3 feet (914 mm) of the water heater.
3. The water heater shall be installed in a space with minimum dimensions of 3 feet (914 mm) by 3 feet (914 mm) by 7 feet (2134 mm) high.
4. The water heater shall be installed in a space with a minimum volume of 700 cubic feet (20,000 L) or the equivalent of one 16-inch (406 mm)

by 24-inch (610 mm) grill to a heated space and one 8-inch (203 mm) duct of no more than 10 feet (3048 mm) in length for cool exhaust air.

R404.6.3 Combustion space heating. Where a building has combustion equipment for space heating, the building shall be provided with a designated exterior location(s) in accordance with the following:

1. Natural drainage for condensate from cooling equipment operation or a condensate drain located within 3 feet (914 mm), and
2. A dedicated branch circuit in compliance with IRC Section E3702.11 based on heat pump space heating equipment sized in accordance with R403.7 and terminating within 3 feet (914 mm) of the location with no obstructions. Both ends of the branch circuit shall be labeled "For Future Heat Pump Space Heater."

> **Exception:** Where an electrical circuit in compliance with IRC Section E3702.11 exists for space cooling equipment.

R404.6.4 Combustion clothes drying. A dedicated 240-volt branch circuit with a minimum capacity of 30 amps shall terminate within 6 feet (1829 mm) of natural gas clothes dryers and shall be accessible with no obstructions. Both ends of the branch circuit shall be labeled with the words "For Future Electric Clothes Drying" and be electrically isolated.

R404.6.5 Combustion cooking. A dedicated 240-Volt, 40A branch circuit shall terminate within 6 feet (1829 mm) of natural gas ranges, cooktops and ovens and be accessible with no obstructions. Both ends of the branch circuit shall be labeled with the words "For Future Electric Range" and be electrically isolated.

R404.6.6 Other combustion equipment. *Combustion equipment* and end-uses not covered by Sections R404.6.2-5 shall be provided with a branch circuit sized for an electric *appliance*, *equipment* or end use with an equivalent capacity that terminates within 6 feet (1829 mm) of the *appliance* or *equipment*.

Revise table as follows:

TABLE R405.2 REQUIREMENTS FOR TOTAL BUILDING PERFORMANCE

SECTION [a]	TITLE
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
R404.6	Additional electric infrastructure

Revise table as follows:

TABLE R406.2 REQUIREMENTS FOR ENERGY RATING INDEX

SECTION [a]	**TITLE**
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
R404.6	Additional electric infrastructure
R406.3	Building thermal envelope

Revise text as follows:

R406.5 ERI-based compliance. Compliance based on an ERI analysis requires that the rated *proposed* design and confirmed built dwelling be shown to have an ERI less than or equal to the appropriate value for the proposed *mixed-fuel building* or the proposed *all-electric building* as indicated in Table R406.4 when compared to the *ERI reference design*.

TABLE R406.4 MAXIMUM ENERGY RATING INDEX

Climate Zone	~~**Energy Rating Index**~~ **All-Electric Building**	**Mixed Fuel Building**
5	55	47
6	54	46
7	53	46

Add new text as follows:

R408.2.3 Reduced energy use in service water-heating option. The hot water system shall meet one of the following efficiencies:

4. Greater than or equal to 82 EF instantaneous fossil fuel service water-heating system and drain water heat recovery unit meeting the requirements of Section R403.5.3 installed on at least one shower.

Michigan EIBC recommends the following demand response language be added to the residential code, including new definitions and new Section C403.4.1.6:

Add new definition as follows:

DEMAND RESPONSIVE CONTROL. An automatic control that can receive and automatically respond to demand response requests from a utility, electrical system operator, or third-party demand response program provider.

Revise text as follows:

R403.1.1 Thermostat ~~Programmable thermostat~~. The thermostat controlling the primary heating or cooling system of the dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature setpoints at different times of the day. This thermostat shall include the capability to set back or temporarily operate the system to maintain zone temperatures of not less than 55°F (13°C) to not greater than 85°F (29°C). The thermostat shall be programmed initially by the manufacturer with a heating temperature setpoint of not greater than 70°F (21°C) and a cooling temperature setpoint of not less than 78°F (26°C). The thermostat shall be provided with a d*emand responsive control* capable of increasing the cooling setpoint between 1°F (0.56°C) and 10°F (5.56°C) in response to a demand response request from a utility, electrical system operator, or third-party demand response program provider.

Add new standard as follows:

CTA	*Consumer Technology Association* *1919 S. Eads Street* *Arlington, VA 22202*	

Standard reference number	*Title*	*Referenced in code section number*
ANSI/CTA-2045-B	*Modular Communications Interface for Energy Management . . . .*	*. R403.5.4*

Energy Monitoring and Renewable Requirements: Commercial Code

It is critical that LARA add the energy monitoring requirements from the 2021 IECC model code, which were removed from the draft, back into Michigan's code. Removing this requirement would significantly impede commercial building owners from maintaining their high-performance buildings at the level originally designed. Building performance, if not properly monitored and maintained, erodes over time, and therefore energy monitoring, in addition to commissioning, would ensure this level as designed is met over the life of the building. If LARA decides to maintain the removal of this important part of the 2021IECC model code, it has the very real potential to erode much of the carbon impact of the new code as the energy savings associated with the new commercial buildings will not be maintained over time. Additionally, the energy monitoring requirements would provide tremendous data sets for energy management professionals to study and improve both the predictive energy modeling efforts in the design phase and the retro-commission process post building occupancy.

In addition to these monitoring requirements, LARA should include on-site nominal renewable generation and energy storage readiness requirements in the commercial energy code. These requirements would support a growing industry in Michigan, reduce carbon emissions, and could reduce costs for commercial business owners while improving reliability and resiliency. Michigan EIBC previously submitted a proposal that would require nominal renewable energy generation onsite with a rated capacity of at least 0.25 Watts/square foot. This requirement would only increase the cost of construction modestly, while saving money on future utility bills. Additionally, Michigan EIBC submitted an amendment to require all new commercial buildings to be energy storage ready, which will ensure that it is economically and technically feasible for commercial business owners to add energy storage on-site. Both of these additions, especially when combined, will support businesses and families in multi-family dwellings by lowering energy bills and providing increased reliability and resiliency. On-site solar plus storage is a critical component for achieving the administration's climate goals, and these requirements in the building code will help to ensure that distributed generation resources are more accessible.

Michigan EIBC recommends LARA add Section 405.12 to C405. 12.5 from the IECC 2021 code back into the state's commercial energy code, which requires energy monitoring for buildings over 25,000 square feet.

Michigan EIBC recommends the following renewable requirement language be added to the commercial code, including new definitions, new section C405.13, and revision to C406.5:

Add new definitions as follows:

> <u>**RENEWABLE ENERGY CERTIFICATE (REC).** An instrument that represents the environmental attributes of one megawatt-hour of renewable electricity; also known as an energy attribute certificate (EAC).</u>

Add new text as follows:

C405.13 On site renewable energy. Each building site shall have equipment for on-site renewable energy with a rated capacity of not less than 0.25 W/ft^2 (2.7 W/m^2) multiplied by the sum of the gross conditioned floor area of the three largest floors.

Exceptions:

1. Any building located where an unshaded flat plate collector oriented towards the equator and tilted at an angle from horizontal equal to the latitude receives an annual daily average incident solar radiation less than 3.5 $kWh/m^2 \cdot day$ (1.1 $kBtu/ft^2 \cdot day$).
2. Any building where more than 80 percent of the roof area is covered by any combination of equipment other than for on-site renewable energy systems, planters, vegetated space, skylights, or occupied roof deck.
3. Any building where more than 50 percent of roof area is shaded from direct-beam sunlight by natural objects or by structures that are not part of the building for more than 2,500 annual hours between 8:00 AM and 4:00 PM.

C405.13.1 Renewable energy certificate documentation. Documentation shall be provided to the code official that indicates that renewable energy certificates (RECs) associated with the on-site renewable energy will be retained and retired by or on behalf of the owner or tenant.

Revise text as follows:

C406.5 Onsite renewable energy. The total minimum ratings of on-site renewable energy systems, not including onsite renewable energy system capacity used for compliance with Section C405.13, shall be one of the following:

Michigan EIBC recommends the following storage readiness language be added to the commercial code, including a revision to C103.2 and new section C405.15:

Revise as follows:

C103.2 Information on construction documents. Construction documents shall be drawn to scale upon suitable material. Electronic media documented are permitted to be submitted when approved by the code official. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed, and show in sufficient detail pertinent data and features of the building, systems and equipment herein governed. Details shall include the following as applicable:

14. Location of pathways for routing of raceways or cable from the electrical service panel and electrical energy storage system area.

15. Location and layout of a designated area for electrical energy storage system.

Add new text as follows:

C405.15 Electric infrastructure for energy storage. Each building site shall have equipment for on-site energy storage not less than 2 feet (610 mm) in one dimension and 4 feet (1219 mm) in another dimension and located in accordance with Section 1207 of the International Fire Code and Section110.26 of the NFPA 70.

Exception: Where an onsite electrical energy system storage system is installed.

C405.15.1 Electrical service reserved space. The main electrical service panel shall have a reserved space to allow installation of a two-pole circuit breaker for future electrical energy storage system installation This space shall be labeled "For Future Electric Storage." The reserved spaces shall be positioned at the end of the panel that is opposite from the panel supply conductor connection.

Conclusion

Thank you for the opportunity to comment on the importance of improving Michigan's energy code. To reiterate, Michigan EIBC is strongly supportive of the advancements the first drafts have already made toward improving energy efficiency of Michigan's homes and buildings, and it is necessary that these advancements remain as LARA makes additional energy efficiency, EV readiness, building electrification, smart thermostats, and renewable energy improvements to the commercial and residential energy codes. We look forward to working with you throughout the remainder of this process.

Thank you,

Michigan EIBC

March 16, 2022

Keith Lambert, Director
Bureau of Construction Codes
Department of Licensing and Regulatory Affairs
State of Michigan
Via email to: LARA-BCC-Rules@michigan.gov

Re: MEECA Comments on Proposed Changes to the Michigan Energy Code

Director Lambert:

The Michigan Energy Efficiency Contractors Association (MEECA) represents companies that work with residential, commercial and industrial customers to save energy through building improvements and other means. We appreciate the opportunity to comment on proposed changes to the Michigan Uniform Energy Code; specifically, 10a Michigan Energy Code (ORR# 2021- 48 LR and 49 LR). Michigan's future prosperity is directly tied to the safety, performance, and affordability of its built infrastructure. Therefore, adopting and enforcing regular improvements to the Michigan Uniform Energy Code is important.

Michigan should adopt 2021 IECC without weakening amendments

MEECA encourages the adoption of the most recent International Energy Conservation Code (IECC) by reference, and with minimal amendments. Benefits of doing so for both residential and commercial codes would include:

- ***Reduced lifecycle building costs***. The improved energy performance reflected in 2021 IECC for new construction and major renovations would protect building owners and renters by lowering operating costs over time, especially given the likely rise in fossil fuel prices going forward. These building improvements would also lead to safer, healthier and more durable structures which hold more value over time.

- ***Greater economic development***. The energy efficiency industry generates jobs which are resistant to export and downsizing because they must be done onsite using skilled human labor. Updating Michigan codes to the 2021 IECC without amendment would bolster this industry and the jobs that it brings.
- ***Improved energy balance of trade***. Michigan relies heavily on imported fossil fuels to power its economy. Investing more in energy efficiency is a proven way to reduce these imports for less than the purchase cost of the displaced fuels. This means keeping more of Michigan's wealth here at home.
- ***Lower greenhouse gas emissions***. Requiring better energy performance in Michigan buildings through adopting 2021 IECC will directly contribute to meeting the state's long-term goal of achieving a carbon neutral economy by 2050.
- ***Keeping Michigan competitive***. The national trend is toward adopting building practices which require better energy performance. Michigan's energy code should be consistent with this trend to remain competitive in attracting more people and business activity to our state.

Michigan should fully enforce the updated code

To be effective, the updated code must be equally enforced in all jurisdictions across Michigan. This has been a challenge in the past. To help address this need, the Bureau should ensure that relevant building professionals receive standardized, continuous training on what the updated code requires and intends. Training should also cover proper installation techniques where there might be confusion about this. The Department and Michigan Legislature should commit to providing the necessary resources to support a permanent building code training program that delivers these results.

By adopting 2021 IECC without amendment, Michigan agencies and building professionals would have access to standardized training materials and programs to help minimize the overall cost of training—and maximize its effectiveness.

Finally, MEECA has a track record of hosting successful code training sessions, and we remain a willing partner in these efforts going forward. Our capacity to engage contractors and other energy efficiency professionals through our industry network would be useful for conducting outreach and convening trainings both virtually and on the ground throughout Michigan.

On behalf of the MEECA membership, thank you for considering these comments on the proposal to update Michigan's energy code.

Respectfully,

David Gard
Executive Director

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
Telephone (517) 582-5519
LARA-BCC-Rules@michigan.gov

My name is Roger Papineau. I live at [redacted].
I am writing today to give comments on the proposed Part 10 and 10a Energy Code Rules.

First, the code sections proposed for deletion, **R 104.2, R 104.3, R 104.4, 104.5, R 109.1, R 109.2, R 109.3, and R 109.4, R 110.1, R 110.2, R 110.3 and R 110.4,** do not exist.
The correct citation format is, **R104.2, R104.3, R104.4, R104.5, R109.1, R109.2, R109.3, and R109.4, R110.1, R110.2, R110.3 and R110.4.**
Second, I am opposed to the wholesale deletion of R 408.31060e. Tables R301.1 and 301.3(2), Figure R301a should be amended to reflect the new designations. Also, R 408.31063 should be retained and amended. There is no reason Michigan users should have to wade through pages of tables of irrelevant information to determine their climate zone and HDD – CDD requirements.
I am also opposed to moving Marquette County to Zone 7. There are 6 other counties in Michigan with similar HDD's, including two in the lower peninsula. The one of three reporting stations reporting the highest HDD's (by 200 HDD) suspicious as that station is on an isthmus between Lake Superior and Lake Independence.
I would also note that the increased R-values and related decrease in U-values do not meet the cost-effective requirements of 125.1502a, Sec.2a., (1), (p), (ii).
Lastly, amend Section R402.4.1.2 to delete the requirement for third party testing. Any qualified blower-door operator/tester should be permitted to submit certified reports. Requiring a third-party tester could result in higher costs the consumer.
Respectfully submitted,
Roger Papineau Builder
[redacted]

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
Phone (517) 241-9303
Fax (517) 241-0130
Email: johnsona39@michigan.gov

ACTION:

DATE: 03/16/2022

NAME: Phil Forner

REPRESENTING: self

ADDRESS: POB 296

CITY: Allendale

STATE: MI

ZIP: 49401

PHONE: (616) 299-0275

FAX:

EMAIL: phil@allendaleheating.com

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.7 Building Cavities.

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**Bold & underline proposed added text**

Building framing cavities <u>not located within the conditioned space</u> shall not be used as ducts or plenums.

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.7 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Prohibiting building cavities from being used as return air ducts within the conditioned space in accordance with Section M1601.1.1 of the Michigan Residential Code will add at least $150 per return air register. So in a typical 3 bedroom home with 4-5 return air registers the added cost will be at least $600-$750 more and save zero energy. The BCC published document titled "2015 Michigan Residential Code Errors and Conflicts" has determined such a prohibition is not cost effective.

☐ **Back Up/Graphic Material Included**

BCC-3016 (05/19)

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
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ACTION:

DATE: 03/16/2022

NAME: Phil Forner

REPRESENTING: self

ADDRESS: POB 296

CITY: Allendale

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FAX:

EMAIL: phil@allendaleheating.com

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.4 - "new exemption"

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**<u>Bold & underline proposed added text</u>**

See attached sheet titled: R403.3.4 - "new exemption"

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.4 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Requiring ducts to be sealed when the ducts are located entirely within the condition space it is serving, is not "cost effective". This "cost effective" rationale was and is being used by the BCC in its published "2015 Michigan Residential Code Errors and Conflicts" document, under Duct Construction. Additionally attached is a supporting analysis by a mechanical engineer who is also a RESNET HERS Rater and LEED AP.

☑ **Back Up/Graphic Material Included**

BCC-3016 (05/19)

R403.3.4 - "new exemption"

PROPOSED LANGUAGE: Show proposed text in accordance with the following format:
Strikeout/**Bold & underline proposed added text**

R403.3.4 Sealing. Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with either the *International Mechanical Code* or *International Residential Code*, as applicable.

<u>Exceptions:</u>
<u>For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), sealing shall not be required where the ducts are located entirely within the condition space it is serving.</u>

2015 Michigan Residential Code Errors and Conflicts

The following are errors and conflicts that have been identified at this point. The Bureau of Construction Codes has reviewed these issues. The Director of Department of Licensing and Regulatory Affairs has delegated the authority to make, and has approved, the following interpretations which are advisory.

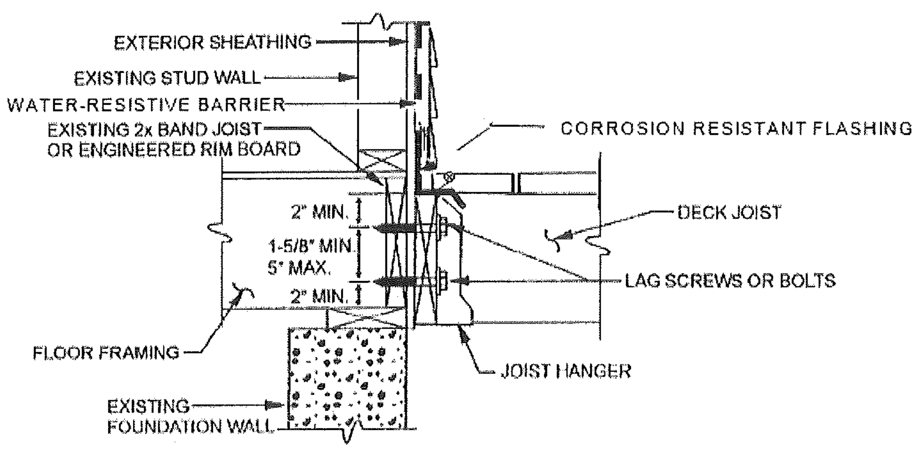
Stair Geometry

In the Michigan Residential Code Section R311.7.4.1 Riser height and Section R311.7.4.2 Tread depth are the correct requirements for stair geometry and they are the promulgated state rules consistent with MCL 125.1513d. These provisions shall replace the provisions in Sections R311.7.5.1 and R311.7.5.2 respectively; however the exceptions in R311.7.5.1 are still valid.

Vapor Retarders

There are 2 sections on vapor retarders in the 2015 Michigan Residential Code, R601.3 and R702.7. It has been determined by the department that section R601.3 is the section that is to be enforced by all enforcing agencies.

Figure R507.2.1(2) was obviously corrupted during the publication of the rules and was not noticed until it was published by the International Code Council. The figure that must be used by all enforcing agencies is now provided.



For SI: 1 inch = 25.4 mm.

FIGURE R507.2.1(2)
PLACEMENT OF LAG SCREWS AND BOLTS IN BAND JOISTS

Carbon Monoxide Detector Location

MRC section R315 does not provide the location of the carbon monoxide detectors. The location of these devices is found in the 1972 PA 230 section 4f, MCL 125.1504f: "A carbon monoxide device shall be located in the vicinity of the bedrooms, which may include 1 device capable of detecting carbon monoxide near all adjacent bedrooms; in areas within the dwelling adjacent to an attached garage; and in areas adjacent to any fuel-burning appliances." They are to be installed in accordance with manufacturer's recommendations and should not be placed within fifteen feet of fuel-burning heating or cooking appliances such as gas stoves, furnaces or fireplaces or in or near very humid areas such as bathrooms.

Duct Construction

The Michigan Residential Code (MRC) Sections N1103.2.3 and M1601.1.1 conflict regarding the use of building framing cavities for plenums. To resolve the conflict we look at the definition of "cost effective" in MCL 125.1502a(p), and MCL 125.1504(3)(f) and (g).

MCL 125.1504a(p) states:
(p) "*Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:*

(i) Considers the perspective of a typical first-time home buyer.

(ii) Considers benefits and costs over a 7-year time period.

(iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.

(iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features."

MCL 125.1504(3)(f) and (g) state:
"*(3) The code shall be designed to effectuate the general purposes of this act and the following objectives and standards:*
(f) To provide standards and requirements for cost-effective energy efficiency that will be effective April 1, 1997.
(g) Upon periodic review, to continue to seek ever-improving, cost-effective energy efficiencies."

The conflict is resolved in favor of M1601.1.1 as MRC Section M1601 is the definitive section on duct construction. This decision is based on MRC Section R102.1 (Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.) and that Section N1103.2.3 has not been shown to meet the definition of cost effective.

Combustible Insulation

Section R302.13 is the language that is promulgated by the department and is the language that must be used. Section R302.14 shall treated as if it was deleted which was the intent.

Roof Loading Data Sheet

Figure 802.10.1 under Exposure Factor C the designation should be B C and D to be consistent with the ASCE 7-10 standard. The text for the exposures is correct but when A was deleted to be consistent with standard an auto correct function relabeled the remaining exposures A, B and C. This was not caught before publication. If the text is used for providing the requested information and A, B and C designation replaced with B. C and D respectively the information will be correct.

Mechanical Resolution

September 7, 2018

Allendale Heating Company, Inc.
11672 60th Avenue – P.O. Box 296
Allendale, Michigan 49401

RE: Duct Sealing

To whom it may concern,

Mr. Irvin Polk issued a 2015 Michigan Residential Code Errors and Conflicts letter to clarify code issues in the 2015 code. In this letter, it addresses the conflict in the code between N1103.2.3 and M1601.1.1 regarding the use of building framing cavities for plenums. Mr. Polk utilized and applied the definition of "cost effective" in MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) to conclude that using building framing cavities for plenums was indeed allowed based on 2015 Michigan Residential Code R102.1. In reviewing and researching this letter, Mr. Polk and I draw the same conclusion in regards to plenums and "cost effective."

Using this same logic, duct sealing ductwork located in a conditioned space would also not meet the definition of "cost effective" under MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) for the very same reasons that the 2015 Michigan Residential Code Error and Conflict determined using building framing cavities for plenums does not meet the definition of "cost effective". Both of these topics are essentially used in the same conversation when discussing building energy efficiency of the HVAC duct system and its' impact on building performance.

Building energy efficiency losses occur when conditioned air is transferred to the environment outside of the building thermal envelope. This occurs via conduction, convection, and radiation through the building structure materials and assemblies. The ways to reduce these losses are by using higher R value building materials, better building fenestration, and decreasing the amount of uncontrolled air leakage into (infiltration) or out of (exfiltration) a building through cracks and seams.

When ductwork is located in a conditioned space, any duct leakage from the unsealed ductwork enters an already conditioned space within the building thermal envelope. Therefore, no energy loss occurs directly related to the sealed and/or unsealed ductwork from a conditioned space to an unconditioned space. Any energy loss would occur from the uncontrolled air leakage through the building envelope and not by an unsealed duct in a conditioned space. There are discussions about how an unsealed duct in a floor/ceiling assembly will positively pressurize the cavity and leak through the exterior cracks. But whether the air pressurizes the cavity or a bedroom (register location), the positive air will find its' way to the crack. Therefore, the real solution to saving energy costs is to seal the crack not necessarily sealing the duct.

Sealing ductwork in an **Un**conditioned space is essential as any duct leakage is lost directly outside the thermal envelope. This is the very reason why code requires duct pressurization testing for ductwork located outside the building thermal envelope (unconditioned space) but does not require the duct pressurization testing for ductwork located inside (conditioned space) the thermal envelope. Blower door testing of the building thermal envelope is required by code no matter where the ductwork is located. This further implies that the code is more concerned with building infiltration, in regards to building efficiency, than to ductwork losses to a conditioned space.

Sealing ductwork in a conditioned space provides better comfort for the homeowner, not energy efficiency nor economic benefits. Duct sealing for comfort helps assure that the necessary airflow is provided to a specific space inside the building thermal envelope. However, when discussing building energy efficiency and economic benefits, a homeowner is better to spend money on reducing building leaks, better insulation, better windows, better doors, as these are the areas where building energy efficiency is lost at the building envelope. Not duct sealing ductwork in a conditioned space.

As stated in the beginning, duct sealing ductwork located in a conditioned space does not meet the definition of "cost effective" under MCL 125.1502 a(p), and MCL 125.1504(3)(f) and (g) for the very same reasons that the 2015 Michigan Residential Code Error and Conflict determined using building framing cavities for plenums does not meet the definition of "cost effective".

Please feel free to call with any questions that you may have.

Respectfully,

Mechanical Resolution

Aaron J. Sedine, P.E.
Mechanical Engineer
Resnet Hers Rater
Leed AP

PROPOSED RULE/CODE CHANGE REQUEST

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes/Administrative Services Division
Attn: Amanda Johnson
PO Box 30254, Lansing, MI 48909
Phone (517) 241-9303
Fax (517) 241-0130
Email: johnsona39@michigan.gov

ACTION:

DATE: 03/16/2022

NAME: Phil Forner	REPRESENTING: self

ADDRESS: POB 296	CITY: Allendale	STATE: MI	ZIP: 49401

PHONE: (616) 299-0275	FAX:	EMAIL: phil@allendaleheating.com

RULE/CODE SECTIONS/TABLES/FIGURES PROPOSED FOR REVISION (Note: If the proposal is for a new section, indicate "new")

R403.3.5 Duct testing - Exception (new)

PROPOSED LANGUAGE: Show proposed text in accordance with the following format: ~~Strikeout~~/**<u>Bold & underline proposed added text</u>**

<u>Exception:</u>
<u>1. A duct air-leakage test shall not be required for ducts serving ventilation systems that are not integrated with ducts serving heating or cooling systems.</u>
<u>2. A duct air-leakage test shall not be required for ducts located in the conditioned space.</u>

REASON: Thoroughly explain the need and reason for the proposed change to include the following:

-Identify the problem.
-Explain the rational for the proposed change.
-Describe the environmental impact.
-Is the proposed change comparable to federal rules or national or regional standards in similarly situated states, based upon geographic location, topography, natural resources, commonalities, or economic similarities? If the proposed change exceeds standards in those states, explain why and specify costs and benefits.
-Identify individuals and groups affected by the proposed change and the impact on these groups.
-Are there any reasonable alternatives to the proposed change? If so, please provide those alternatives.
-What is the fiscal impact for the proposed change? Provide a cost/benefit analysis.
-Estimate the actual statewide compliance costs of the proposed rule.
-What are the primary and direct benefits of the rule?
-Estimate any cost increases or reductions to businesses, individuals, groups, or governmental units as a result of the rule.

As well as any other information appropriate to assist with a clear understanding of the issue. During the rulemaking process, the need and reasoning of all proposed rule changes should be identified. By including a detailed explanation, the general public will gain a better understanding on all aspects of the proposal. Providing an explanation on the need and rationale for the proposal is optional; however, MCL 24.245 requires the department to provide proper justification for each proposal. Without this important information, the department may not be able to document appropriate justification and merit for a proposal. For further information, please refer to the Administrative Procedures Act of 1969.

The Bureau Construction Codes (BCC) has not provided any analysis showing that the provisions of R403.3.5 is "cost effective" as required by MCL 125.1502a(p), and MCL 125.1504(3)(f)-(g). Ducts located in the conditioned space and leak air in to the same conditioned space does not contribute to the overall buildings increased energy use. Therefore to require a $300-$500 air duct leakage test is not cost effective as it will save zero energy.

□ **Back Up/Graphic Material Included**

I would like to propose an amendment to the IECC 2021 (MEC 2021).

Currently, the specifications for the MEC 2015 Standard Reference Design (From page 454 of the MRC 2015) for the Air Exchange Rate are 4ACH@50Pa:

TABLE N1105.5.2(1) [R405.5.2(1)]—continued
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Air exchange rate	Air leakage rate 4 of air changes per hour at a pressure of 0.2 inches w.g (50 Pa). The mechanical ventilation rate shall be in addition to the air leakage rate and the same as in the proposed design, but no greater than $0.01 \times CFA + 7.5 \times (N_{br} + 1)$ where: *CFA* = conditioned floor area N_{br} = number of bedrooms Energy recovery shall not be assumed for mechanical ventilation.	The measured air exchange rate[c]. The mechanical ventilation rate[d] shall be in addition to the air leakage rate and shall be as proposed.

The rate for the IECC 2021 (page R4-16) is considerably lower at 3.0ACH@50Pa:

Air exchange rate	The air leakage rate at a pressure of 0.2 inch w.g. (50 Pa) shall be Climate Zones 0 through 2: 5.0 air changes per hour. Climate Zones 3 through 8: 3.0 air changes per hour.	The measured air exchange rate.[a]
	The mechanical ventilation rate shall be in addition to the air leakage rate and shall be the same as in the proposed design, but not greater than $0.01 \times CFA + 7.5 \times (N_{br} + 1)$ where: *CFA* = conditioned floor area, ft^2. N_{br} = number of bedrooms. The mechanical ventilation system type shall be the same as in the proposed design. Energy recovery shall not be assumed for mechanical ventilation.	The mechanical ventilation rate[b] shall be in addition to the air leakage rate and shall be as proposed.

I propose that the Standard Reference Design Air Exchange Rate remain at 4.0ACH@50Pa as it is currently. This will encourage builders to reduce air leakage as much as is practical so as to obtain performance credit for air leakage rates less than 4.0ACH@50Pa.

Proposed text amendment:

The air leakage rate at a pressure of 0.2 inch w.g. (50Pa) shall be Climate Zones 0 through 2: 5.0 air changes per hour. Climate Zones 3 through 8: 4.0 air changes per hour.

Respectfully submitted

Don Nelson

D.R. Nelson and Associates, Inc.
www.drnelson.com
[redacted]

AIA Detroit

Building Codes & Regulations Committee
Professional Chapter of the International Code Council

15 March 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
LARA-BCC-Rules@michigan.gov

RE: 10a Michigan Energy Code (ORR# 2021-49 LR)

We are writing in support of including the IECC appendices, specifically Appendix CC, in the Michigan Commercial Building Code. Currently, unlike the ASHRAE appendices, they are not specifically included in the current draft language.

IECC 2021 Appendix CC (aka Zero Code) is a flexible framework that cities and states can use to help reach their building decarbonization goals. IECC 2021 Appendix CC combines energy efficiency and renewable energy to support the construction of code-compliant, zero carbon buildings that use clean energy. It applies to new commercial, industrial and mid- to high-rise residential buildings—the dominant building types being constructed in cities today.

As a VOLUNTARY Appendix, it gives any Authority Having Jurisdiction the option of adopting the appendix. It does not make the appendix mandatory across the State. This provides jurisdictions an important framework to reach their decarbonization goals, if they choose to adopt the appendix.

In summary we support Appendix CC because:

- Voluntary for jurisdictions to adopt
- Compliance with 2021 IECC is required
- Sets a minimum renewable energy requirement based on energy simulations or default values
- Provides an incentive for buildings to be designed to be more energy efficient than code requires
- Encourages on-site renewable energy when feasible
- Supports off-site renewable energy procurement when necessary
- 2021 IECC energy efficiency requirements cannot be traded with renewable energy
- Establishes a consistent framework that local governments can modify for their specific needs and conditions

Sincerely,

Justin James Bialek, AIA, NCARB, AIAD BC&RC Chair

March 16, 2022

Keith Lambert, Director
Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

RE: Pending Rule Set #2021-48 LR and #2021-49 LR, Supplemental Comments of the Responsible Energy Codes Alliance (RECA) Supporting the Adoption of the 2021 *IECC* as the Michigan Construction Code Parts 10 and 10a

Dear Director Lambert,

In the February 9, 2022 Draft Rules circulated by the Department for public comment,[1] the Department proposes to adopt the 2021 International Energy Conservation Code (*IECC*) for residential and commercial buildings in Michigan. **The Responsible Energy Codes Alliance supports the Department's proposed Draft Rules and offers the following supplemental comments.**

At the outset, we note that on July 16, 2021, the Responsible Energy Codes Alliance submitted a letter to the Department generally supporting the adoption of the 2021 *IECC* in Michigan. We incorporate that letter by reference in these comments. In these comments, we will not repeat the information in our previous letter, but instead we wish to provide a summary of additional information now available that confirms that **adoption of the 2021 *IECC* will provide substantial benefits to Michigan in four specific ways:**

1. **The 2021 *IECC (Residential Provisions)* will provide cost-effective energy savings for residential homeowners and will provide economic benefits for the whole state;**
2. **The 2021 *IECC (Commercial Provisions)* will provide cost-effective energy savings for the owners and occupants of commercial and high-rise multifamily buildings and bring additional economic benefits for the whole state;**

[1] *See* Department of Licensing and Regulatory Affairs, *Request for Rulemaking*, Construction Code – Part 10, Michigan Uniform Energy Code, Pending Rule Set #2021-48 LR (June 15, 2021) and Department of Licensing and Regulatory Affairs, *Request for Rulemaking*, Construction Code – Part 10a, Michigan Energy Code, Pending Rule Set #2021-49 LR (June 15, 2021).

3. **The 2021 *IECC* will support the state's efforts achieve several goals outlined in Executive Directives 2019-12 and 2020-10[2] and the Michigan Healthy Climate Plan[3]; and**

4. **The 2021 *IECC* will provide a range of health, safety, and resiliency benefits for Michiganders, and will help reduce energy and housing inequity.**

The available information makes a compelling case that the best path forward in this arena for Michigan is the complete adoption of the 2021 *IECC* as the Michigan Construction Code, Parts 10 and 10a, as proposed in the February 9, 2022 Draft Rules issued by the Department.

1. **The 2021 *IECC* provides cost-effective energy savings for residential homeowners and will provide economic benefits for the whole state.**

In our July 2021 comments, we cited an analysis conducted by the U.S. Department of Energy that showed the clear cost-effectiveness of the improvements in the 2021 *IECC* for the nation as a whole. Since then, U.S. DOE (through the Pacific Northwest National Laboratory) has analyzed the energy savings and cost-effectiveness of the 2021 *IECC* specifically for Michigan residential homeowners, as compared with Michigan's current residential energy code (the 2015 *IECC* with amendments). A summary of U.S. DOE's conclusions is below:

Individual Residential Consumer Impact of 2021 *IECC* (statewide averages)[4]

Metric	Compared to 2015 *IECC* with MI-specific amendments
Annual Energy Cost Savings	10.7%
Net annual consumer cash flow in year 1 of the 2021 *IECC*	$97
Life-cycle cost savings of the 2012 *IECC*	$4,514
Years to positive savings, including up-front cost impacts	5

[2] *See* Responding to Climate Change, Executive Directive 2019-12, *available at* https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-488740--,00.html, and Building a Carbon-Neutral Michigan, Executive Directive 2020-10, *available at* https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html.

[3] Department of Environment, Great Lakes, and Energy, *Draft MI Healthy Climate Plan* (Jan. 14, 2022), *available at* https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.

[4] See U.S. Dep't of Energy, Cost-Effectiveness of the 2021 *IECC* for Residential Buildings in Michigan, at ii, 3 (July 2021), *available at* https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf.

U.S. DOE conducted its multi-year analysis of the costs and benefits of the code update from the perspective of the homeowner. Notably, the net annual consumer cash flow (which is the annual energy savings minus the increased mortgage, insurance, taxes, etc.) is positive in year one: **On average, the owners of Michigan homes constructed to the 2021 *IECC* would see a positive cash flow of $97 within the first year of the home's lifetime.** And homeowners would see positive savings (including all up-front costs) within an average of five years. It is clear that the economic benefits of adopting the 2021 *IECC* will exceed the costs of the update within a reasonable time frame and will continue to pay homeowners a solid return on investment for decades after the home is constructed. The lower energy costs associated with a home built to the 2021 *IECC* will not only benefit the first owner of the home but will benefit every subsequent owner of the home over the home's useful life.

Although much of the discussion regarding energy code improvements tends to focus on the individual homeowner, it is also important to consider the impacts of these improvements on the entire state. U.S. DOE estimates that if the 2021 *IECC* is applied to all new residential construction in Michigan, the statewide energy cost savings would be $3,873,000 in the first year.[5] Over the next 30 years, these savings would balloon to $1,251,000,000.[6]

These savings can be captured while also providing a net increase in jobs created as a result of these code improvements. According to U.S. DOE's analysis (summarized in the table below), the adoption of the 2021 *IECC* would create thousands of new jobs in Michigan. Improved building efficiency brings about a net increase in jobs in two ways: (1) by an increase in construction-related activities associated with the improvements contained in the latest codes; and (2) by a reduction in utility bills, which will result in an increase in disposable household income, which can be spent on other goods and services in the local economy.

Statewide Impact – Jobs Created[7]

Statewide Impact	First Year	30 Years Cumulative
Jobs Created – Construction Related Activities	187	4,851
Jobs Created – Reduction in Utility Bills	257	6,675

[5] *See* U.S. Dep't of Energy, *Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan*, at iii (July 2021).

[6] *Id*.

[7] *Id.*

2. **The 2021 *IECC* will provide cost-effective energy savings for the owners and occupants of commercial and high-rise multifamily buildings and bring additional economic benefits for the whole state.**

U.S. DOE also conducted a thorough cost-effectiveness analysis of the improvements in *ASHRAE* Standard 90.1-2019 and Standard 90.1-2016, both of which would be incorporated into the proposed update to Michigan's current commercial and high-rise multifamily energy code, *ASHRAE* Standard 90.1-2013. As with the analysis of the residential model energy code, the cost-effectiveness and economic benefits of the latest commercial model energy code are clear.

Consumer Impacts of ASHRAE Standards 90.1-2016 and 90.1-2019[8]

Metric	Standard 90.1-2016[9]	Standard 90.1-2019[10]
Energy Cost Savings over Previous Model Energy Code (national avg.)	**8.3%**	**4.3%**
Annual Cost Savings, $/sq. ft (statewide avg.)	$0.123	$0.063
Added Construction Cost, $/sq. ft (statewide avg.)	-$0.248	-$1.198
Life Cycle Cost Savings - publicly owned buildings, $/sq. ft (statewide avg.)	$8.60	$4.22
Life Cycle Cost Savings - privately owned buildings, $/sq. ft (statewide avg.)	$7.09	$3.70

[8] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ASHRAE Standard 90.1-2016 for the State of Michigan*, at 1 (August 2020), *available at* https://www.energycodes.gov/sites/default/files/2021-03/Cost-effectiveness_of_ASHRAE_Standard_90-1-2016-Michigan.pdf, *and* U.S. Dep't of Energy, *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2016*, at iv (October 2017), *available at* https://www.energycodes.gov/sites/default/files/2021-07/02202018_Standard_90.1-2016_Determination_TSD.pdf.

[9] *Id.*

[10] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Mihcigan*, at 1 (July 2021), *available at* https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Michigan.pdf *and* U.S. Dep't of Energy, Energy Savings Analysis: ANSI/*ASHRAE*/IES Standard 90.1-2019, at vi (July 2021), *available at* https://www.energycodes.gov/sites/default/files/2021-07/Standard_90.1-2019_Final_Determination_TSD.pdf.

According to this analysis, the improvements included in 2019 version of the ASHRAE Standard will produce cumulative energy cost savings for building owners/occupants over the 2013 version of well over 10%.

Our understanding is that the Draft Rule would allow compliance with either the 2021 *IECC* commercial provisions or *ASHRAE* Standard 90.1-2019, whereas the current code largely references only the requirements of *ASHRAE* Standard 90.1-2013. We support this improvement, which would allow design professionals and builders the option to build to either model code — enhancing flexibility while providing comparable energy savings and cost-effectiveness.

Because the commercial energy code covers a wide range of building occupancy types, there will obviously be a range of energy savings, life cycle cost savings, and payback periods. However, we note that in many cases, the improvements contained in Standards 90.1-2016 and 90.1-2019 were found to have immediate paybacks as compared to the current code. In other words, for these occupancy types, the latest codes would actually *reduce* construction costs, if followed properly. Below are two tables from the U.S. DOE Technical Support Documents for these two editions of Standard 90.1 that indicate the average savings and payback periods for various occupancy types:

U.S. Department of Energy, *Cost-Effectiveness of ASHRAE Standard 90.1-2016 for the State of Michigan,* Table 6 *Simple Payback for Michigan (Years)*[11]

Table 6. Simple Payback for Michigan (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	2.9	5.3	6.7	Immediate	Immediate	Immediate	2.0
6A	3.5	9.4	6.3	Immediate	Immediate	Immediate	2.5
7	4.1	10.8	6.2	Immediate	Immediate	Immediate	0.2
State Average	3.0	5.2	6.7	Immediate	Immediate	Immediate	**2.0**

[11] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ASHRAE Standard 90.1-2016 for the State of Michigan*, at 4 (Aug. 2020).

U.S. Department of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Michigan,* Table 6 *Simple Payback for Michigan (Years)*[12]

Table 6. Simple Payback for Michigan (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	Immediate	Immediate	Immediate	Immediate	8.2	Immediate	Immediate
6A	Immediate	Immediate	Immediate	Immediate	8.6	Immediate	Immediate
7	Immediate	Immediate	Immediate	Immediate	10.8	Immediate	Immediate
State Average	Immediate	Immediate	Immediate	Immediate	8.8	Immediate	**Immediate**

Although simple payback analyses are limited in scope, and do not capture the full life cycle benefits of efficiency improvements, it is notable that even an analysis that considers only first costs shows short or immediate paybacks for the two most recent editions of Standard 90.1. Based on all of the most common cost-effectiveness metrics commonly used to assess building energy code improvements, the improvements contained in *ASHRAE* Standards 90.1-2016 and 90.1-2019 are solid investments for the owners of commercial and high-rise multifamily buildings.

As with the residential energy code update, U.S. DOE estimates that if *ASHRAE* Standard 90.1-2019 is applied to all new commercial and high-rise multifamily construction in Michigan, the additional statewide cost savings in the first year alone would be $1,587,000.[13] Over the next 30 years, these savings would reach $683,500,000.[14] According to DOE's analysis, adopting the latest model energy codes for commercial buildings would also create jobs in Michigan in two ways: (1) The improved building techniques and materials specified in more efficient building codes will spur an increase in construction-related activity; and (2) The reduction in utility bills will result in an increase in disposable income, which generates economic benefits in local economies. A summary of this analysis is in the table below:

[12] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Michigan*, at 5 (July 2021).
[13] *Id*. at 1.
[14] *See id*.

Statewide Impact – Jobs Created[15]

Statewide Impact	First Year	30 Years Cumulative
Jobs Created – Construction Related Activities	127	4,008
Jobs Created – Reduction in Utility Bills	186	5,896

3. **The 2021 *IECC* will help Michigan achieve the goals outlined in Executive Directives 2019-12 and 2020-10 and the Michigan Healthy Climate Plan.**

In 2019, Michigan joined the Paris Accord through Executive Directive 2019-12[16], followed by more specific measures outlined in Executive Order 2020-10, which included commitments to achieving "economy-wide carbon neutrality no later than 2050," and a "28% reduction below 2005 levels in greenhouse gas emissions by 2025."[17] To facilitate these objectives, Executive Directive 2020-10 directed the creation of the Michigan Healthy Climate Plan, the first draft of which was published January 14, 2022.[18]

The Michigan Healthy Climate Plan specifically recommends adopting the 2021 Model Energy Code (the 2021 *IECC*) with no weakening amendments.[19] The Buildings and Housing Workgroup found that:

> The building energy conservation code adoption process is one of the few regulatory levers that state decision-makers have to improve our building stock over time to the benefit of Michiganders and our economy. Building codes ensure that new construction and major renovation projects are better and safer. They also influence what products are readily available on the market for contractors and help

[15] *Id*.

[16] *See* Responding to Climate Change, Executive Directive 2019-12, *available at* https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-488740--,00.html.

[17] *See* Building a Carbon-Neutral Michigan, Executive Directive 2020-10, *available at* https://www.michigan.gov/whitmer/0,9309,7-387-90499_90704-540278--,00.html.

[18] *See* Michigan Department of Environment, Great Lakes, and Energy, *Draft MI Healthy Climate Plan*, *available at* https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.

[19] *Id*. at 11. *See also Michigan Council on Climate Solutions: Buildings and Housing Workgroup Recommendations*, at 9 (Sep. 2021), *available at* https://www.michigan.gov/documents/egle/Workgroup-Recommendations-Buildings-Housing_739165_7.pdf.

standardize construction practices across the industry even in projects where codes don't apply.[20]

The Healthy Climate Plan called out efficiency as one of the "two pillars of clean energy," and one of most beneficial means of achieving climate goals:

> Energy waste reduction strategies such as improving insulation, installing energy-saving lighting, and investing in more efficient factory equipment. Making the most of energy waste reduction opportunities throughout the state is the fastest and surest way to make progress in reducing Michigan's GHG footprint. When it comes to reducing harmful emissions—and saving money for Michigan families and businesses—it's hard to get more bang for the buck than cutting energy use.[21]

Adopting the energy provisions of the 2021 *IECC* and *ASHRAE* Standard 90.1-2019 will also help Michigan reduce peak electric demand and associated greenhouse gas emissions. In addition to analyzing the energy savings of the latest model codes, U.S. DOE also studied the potential statewide emissions reductions associated with adopting these codes. A combined summary of these findings is in the table below.

Statewide Impact - Emissions[22]

Combined Impact of Adopting 2021 *IECC* and *ASHRAE* Standard 90.1-2019	First Year	30 Years Cumulative
CO_2 emission reduction, Metric tons	39,350	21,490,000
CH_4 emissions reductions, Metric tons	3.13	1,745
N_2O emissions reductions, Metric tons	0.44	246
NOx emissions reductions, Metric tons	27.89	15,177
SOx emissions reductions, Metric tons	27.38	15,383

To put these emissions reductions into perspective, DOE estimates that the 30-year impact of CO2 reductions alone (through the adoption of the 2021 *IECC* and *ASHRAE* Standard 90.1-2019) is equivalent to taking 4,675,000 cars off the road.[23] According to the

[20] *See Michigan Council on Climate Solutions: Buildings and Housing Workgroup Recommendations*, at 9 (Sep. 2021), *available at* https://www.michigan.gov/documents/egle/Workgroup-Recommendations-Buildings-Housing_739165_7.pdf.

[21] *See* Michigan Department of Environment, Great Lakes, and Energy, *Draft MI Healthy Climate Plan*, at 14.

[22] *See* U.S. Dep't of Energy, *Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan*, at iii (July 2021), and U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Michigan*, at 1 (July 2021).

[23] *Id.*

U.S. Energy Information Administration, residential and commercial buildings account for nearly 40% of total energy consumption,[24] so in order for Michigan to make meaningful progress toward reducing air pollutant emissions as envisioned by the Executive Directives, the energy used in buildings must be addressed.

4. **Adopting the 2021 *IECC* will provide health, safety, and resiliency benefits for Michiganders, and will help reduce energy and housing inequity.**

Efficient homes with lower operating costs will also contribute to the health and safety of building occupants in several ways. High energy bills can have dramatic effects on quality of life. The U.S. Energy Information Administration recently reported that nearly one in three households struggle to pay energy bills or to maintain adequate temperatures in their homes every year. Worse, one in five households reported reducing or foregoing basic necessities like food or medicine to pay energy bills.[25] More efficient buildings provide a range of additional health, safety, and welfare benefits, including better indoor environmental quality and increased occupant comfort.[26] More efficient buildings are also associated with lower foreclosure rates.[27] Efficient buildings also play critical roles in community and household resilience. [28] Buildings constructed to the latest efficiency standards can improve passive survivability during extreme heat or cold weather events.

Efficient buildings can also play a substantial role in reducing energy and housing inequity. According to a recent report by the American Council on an Energy Efficient Economy, the negative impacts of high energy bills are felt more acutely in lower-income households, which spend three times more of their income (on a percentage basis) on energy costs as compared to the median spending of non-low-income households. Black,

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[24] *See Frequently Asked Questions (FAQs): How Much Energy is Consumed in U.S. Buildings,* U.S. Energy Infrastructure Admin., available at https://www.eia.gov/tools/faqs/faq.php?id=86&t=1s.

[25] *See* U.S. Energy Information Administration, *Residential Energy Consumption Survey (RECS)*, at https://www.eia.gov/consumption/residential/reports/2015.

[26] *See* U.S. Environmental Protection Agency, *Improving Indoor Air Quality*, at http://www.imt.org/uploads/resources/files/IMT_UNC_HomeEEMortgageRisksfinal.pdf.).

[27] *See* UNC Center for Community Capital and Institute for Market Transformation, *Home Energy Efficiency and Mortgage Risks* (March 2013), available at http://www.imt.org/uploads/resources/files/IMT_UNC_HomeEEMortgageRisksfinal.pdf.

[28] *See, e.g.*, International Code Council, *The Important Role of Energy Codes in Achieving Resilience*, at 13 (available at https://www.google.com/url?client=internal-element-cse&cx=011680485502119705034:96joabtwwby&q=https://www.iccsafe.org/wp-content/uploads/19-18078_GR_ANCR_*IECC*_Resilience_White_Paper_BRO_Final_midres.pdf&sa=U&ved=2ahUKEwj_sMjLzpP2AhX_l3IEHe_lDSUQFnoECAgQAQ&usg=AOvVaw3gBiWfyOJeLydlzqGTRvqh. "Using energy codes to provide enhanced passive survivability provides significant co-benefits. Community and individual resilience is enhanced while building owners and tenants reap energy efficiency related rewards everyday in the form of lower energy bills and greater cost certainty."

Hispanic, and Native American households, as well as households with older adults, all have disproportionately higher energy burdens as compared to the national median households.[29] The Healthy Climate Plan recognizes the long-term economic value of updated building energy codes, estimating that for every $1 invested in reducing energy waste in homes, through improving envelope efficiency and other measures, will save homeowners more than $3.30 in reduced future energy bills.[30] It is vitally important that every new building be constructed in a way that minimizes operation and maintenance costs for owners and occupants, since these buildings will be part of Michigan's building stock for 70 years or more.

Conclusion

RECA's members support the work of the Department to improve the lives of Michiganders and to reduce the harmful effects of greenhouse gases. We encourage the Department to finalize and implement the February 9, 2022 Draft Rules as quickly as practicable. Please contact us if you have any questions or would like to discuss how RECA can be of assistance.

Sincerely,

Eric Lacey
RECA Chairman

[29] American Council for an Energy Efficient Economy, *How High Are Household Energy Burdens?* at iii (Sept. 2020), *available at* https://www.aceee.org/sites/default/files/pdfs/u2006.pdf.

[30] *See* Michigan Department of Environment, Great Lakes, and Energy, *Draft MI Healthy Climate Plan*, at 4.

RECA is a broad coalition of energy efficiency professionals, regional efficiency organizations, product and equipment manufacturers, trade associations, and environmental organizations with expertise in the development, adoption, and implementation of building energy codes nationwide. RECA is dedicated to improving the energy efficiency of homes throughout the U.S. through greater use of energy efficient practices and building products. It is administered by the Alliance to Save Energy, a non-profit coalition of business, government, environmental and consumer leaders that supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers. Below is a list of RECA Members that endorse these comments.

Air Barrier Association of America

Alliance to Save Energy

American Chemistry Council

American Council for an Energy-Efficient Economy

CertainTeed LLC

EPS Industry Alliance

Extruded Polystyrene Foam Association

Institute for Market Transformation

Johns Manville Corporation

Knauf Insulation

National Fenestration Rating Council

Natural Resources Defense Council

North American Insulation Manufacturers Association

Owens Corning

Polyisocyanurate Insulation Manufacturers Association

AIA Huron Valley

15 March 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
LARA-BCC-Rules@michigan.gov

RE: 10a Michigan Energy Code (ORR# 2021-49 LR)

We are writing in support of including the IECC appendices, specifically Appendix CC, in the Michigan Commercial Building Code. Currently, unlike the ASHRAE appendices, they are not specifically included in the current draft language.

IECC 2021 Appendix CC (aka Zero Code) is a flexible framework that cities and states can use to help reach their building decarbonization goals. IECC 2021 Appendix CC combines energy efficiency and renewable energy to support the construction of code-compliant, zero carbon buildings that use clean energy. It applies to new commercial, industrial, and mid- to high-rise residential buildings, the dominant building types being constructed in cities today.

As a VOLUNTARY Appendix, it gives any Authorities Having Jurisdiction the option of adopting the appendix. It does not make the appendix mandatory across the State. This provides jurisdictions an important framework to reach their decarbonization goals if they choose to adopt the appendix.

In summary we support Appendix CC because:

- Voluntary for jurisdictions to adopt
- Compliance with 2021 IECC is required
- Sets a minimum renewable energy requirement based on energy simulations or default values
- Provides an incentive for buildings to be designed to be more energy efficient than code requires
- Encourages on-site renewable energy when feasible
- Supports off-site renewable energy procurement when necessary
- 2021 IECC energy efficiency requirements cannot be traded with renewable energy
- Establishes a consistent framework that local governments can modify for their specific needs and conditions

Sincerely,

Anne M. Cox, AIA
President
AIA Huron Valley

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Ann Arbor, MI 48106

AIA Grand Rapids

16 March 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
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LARA-BCC-Rules@michigan.gov

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Sincerely,

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